Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 183 APRIL, 1917 No. 4

BY-PRODUCT COKE AND COKING OPERATIONS.*

BY

C. J. RAMSBURG,

Second Vice-President,

AND

F. W. SPERR, JR.,

Chief Chemist, The H. Koppers Company, Pittsburgh, Pa.

THERE has been so much written and published bearing on the surprisingly large development in the building of by-product coke ovens that it seems unnecessary further to emphasize this point in detail. Suffice it to say, that on January 1, 1915, there were in operation 6438 by-product recovery ovens of various sizes in the United States and Canada, having a capacity to carbonize 24,000,000 tons of coal per annum, and to produce therefrom approximately 18,800,000 tons of coke. Despite the fact that in the interim practically five hundred ovens have been discarded, on January 1, 1918, there will be in operation, if present contracts are completed, 9900 ovens, having a capacity to carbonize 47,400,000 tons per annum, giving a coke production of 35,000,000 tons. In this three-year period by-product coke production will have practically doubled, and there will have been as much gain in capacity as in the previous twenty years.

The cause of this rapid increase has not been a desire to take

* Presented by Mr. Ramsburg at a joint meeting of the Mechanical and Engineering Section and the American Society of Mechanical Engineers, held Thursday, February 1, 1917.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1917, by THE FRANKLIN INSTITUTE.

advantage of the inflated prices for by-products due to war conditions, but a financial condition favoring large investments brought about by the war, and making it possible to carry forward plans made previously for such development when opportunity presented. That many of the plants have been completed and put into operation at a time when they might take advantage of the high prices for tar, ammonia, and benzols is a fortunate coincident and not a contributory cause.

While one is much impressed by the amount of money saved from the recovery of these by-products and by the stimulus given to the chemical and manufacturing industries by the supply of such an abundance of raw materials, the most impressive fact is the conservation of our coal supply brought about by the introduction of modern methods. It may be of interest to put aside, for the moment, the question of profits obtainable from the sale of ammonium sulphate and other by-products as materials of chemical industry and to make a few calculations simply from the standpoint of *fuel values*. To put the matter on the most conservative basis possible, let us figure such values in terms of coal.

Table I (p. 393) shows the fundamentals of the matter from this standpoint.

This table shows a total fuel saving of 825 pounds of coal per ton of furnace coke. Please note in this that the fuel value of the gas is put not at its value compared with the coal necessary to replace it with producer gas, which is necessarily made at a low efficiency, but as against raw *coal*, B. T. U. for B. T. U. There is a further saving in the blast furnace. Reports from a large number of blast furnace plants indicate that a saving of 200 pounds of coke per ton of beehive coke formerly used is a conservative average figure. Figured back on a coal basis, these 200 pounds of coke represent 282½ pounds of coal at the beehive oven, so that the total saving amounts to approximately 1100 pounds of coal—0.55 ton—for each ton of by-product coke made in the modern plant.

Since the ovens gained in operation from January 1, 1915, to 1918 will produce practically 16,200,000 tons of coke per annum, it follows that these ovens will save annually to this country the fuel equivalent of 9,000,000 tons of coal. While it is true that the total coal resources of America have up to this time

hardly been scratched, nevertheless it is important to emphasize that this saving is taking place in low ash, low sulphur, high-grade coking coal—coal which, from its mining locations, naturally carries the most favorable freight and labor conditions, and as such is of vast importance—to us and to posterity.

Looking backward over the years consumed in bringing the coke oven to its present stage of development in America, there

Table I.

By-product Yields from Coal Such as Now Used to Make First-class By-product Coke in the Middle States District. 85 per cent. High Volatile, 15 per cent. Low Volatile.

		Fuel value equivalent, pounds of coal.
To make 1 Ton Furnace Coke.	*Surplus Gas.* 9000 *cubic feet, 550 B. T. U. Used as fuel.*	350
	Tar. 12 *gallons.* Used to make creosote oil, pitch, lampblack, various oils and dye materials.	133
1.4—1.5 Tons Coal Required. By beehive coking, the by-products wasted have a heat value equivalent to 625 pounds of coal. At least 200 additional pounds of coal are wasted in the process of beehive coking by combustion.	*Ammonium Sulphate.* 33 *pounds* (or, in form of 25 per cent. ammonia liquor, 33 pounds). Used for fertilizer, for refrigeration, and for nitric acid and other chemical manufactures.	(*No fuel equivalent*)
	Benzols (as light oil). 4.5 *gallons.* Used for motor fuel, dye material base, phenol and other chemical manufacture, solvent and cleanser	42
	Coke Breeze. 120 *pounds* Used as fuel.	100
	Total	625
	Add coal equivalent wasted in beehive oven	200
	Total economy of by-product oven per ton coke	825

are a number of events and conditions which stand out pre-eminently and may be considered as the high spots in progress. The first of these dates back to 1906. In that year the United States Steel Corporation was brought face to face with the necessity of formulating a definite policy as to its coke supply, and, in preparation, appointed a committee of its leading engineers and works managers, whose object was to study beehive coking and by-

product coking and to make a recommendation to the company as to the course to pursue after a comprehensive study of the whole matter. This committee did not restrict its investigations to America, but spent a long period in England, Germany, and Austria, studying with great care and attention to detail the most minute phases of the various processes submitted for consideration. It has been said that the report of this committee, which was headed by Mr. G. G. Crawford, now president of the Tennessee Coal, Iron and Railroad Company, was one of the finest and most complete reports ever presented on an engineering and general technical subject.

The advice of this committee was quickly acted upon by the Corporation in the decision to build a by-product oven plant at Joliet, Ill., in connection with the blast furnace and steel plant of the Illinois Steel Company, and to build that type of oven which they had found to be giving the most efficient results in the European countries.

The success of this Joliet plant was so immediate, not only from a standpoint of economy of coke manufacturing, but in the increased blast furnace capacity and efficiency, that the Corporation without delay proceeded with the construction of additional plants of the same type, including the largest by-product coke plant in the world at Gary, Ind., consisting of 560 Koppers ovens, and a plant of approximately the same size as the Joliet plant (280 ovens) at Ensley, Ala., for the Tennessee Coal, Iron and Railroad Company.

The second high spot was the selection of silica material for one of the oven batteries at Joliet.

While some silica had been used on other types of ovens previous to this time, the use of it in the ovens of the Koppers type, with their inherent qualities of uniform heating due to their *basic heating principles,* intensified the value of this type of oven enormously, and put a new aspect on the entire coke situation. The value of the silica in this connection is due to four characteristics.

First.—The conductivity at high temperatures is superior to that of clay brick.

Second.—The fusing or softening temperature is much higher than that of fire clay.

Third.—The action under heat may be calculated with scientific exactness, due to its practically constant composition.

Fourth.—The expansion and contraction of silica material between 2000° F. and 2600° F. is practically negligible, so that when the material has once been heated to within this temperature range (under which condition the coking operations are conducted) no further appreciable movement takes place.

The Koppers oven is designed to utilize all of these characteristics to great advantage. From the time that the silica battery (one of four) was first built at Joliet, Ill., no Koppers oven has been built in America of any other material.

The third high spot might be better represented by some other simile, since it was more gradual in its development. It consisted in a realization that with uniform heat distribution in the ovens and with the use of silica material much higher heats and consequent higher coking velocities could be employed, and, further, that, with the lower coking periods, higher volatile coals could be used, with increased yields of by-products and equally satisfactory coke.

The result can be demonstrated by the fact that the Joliet plant of the United States Steel Corporation, put into operation in 1908, was originally planned to use from 70 to 80 per cent. of low volatile coal, and the coking time was figured at 24 hours. The Koppers Company is now building at Clairton, Pa., near Pittsburgh, a coke plant for the Steel Corporation of 640 ovens, and the plant is so designed that it may be operated on 15 hours' coking time and is expected to use 100 per cent. high volatile coal. Even if the 100 per cent. high volatile coal proves not to make quite as high grade furnace coke as the coke at Joliet, its use will work out on broad lines to better purpose and time will tell where the comparison lies, after opportunity has been given the furnace operators to adjust themselves to the new type of coke.

The effect on the products can best be shown by reference to Table II.

Table II.

YIELDS OF BY-PRODUCTS PER TON COKE.

	Coal Mixture A. 80 per cent. low volatile. 20 per cent. high volatile.	*Coal Mixture B.* 100 per cent. high volatile.
Tar	6.5 gallon.	13.5 gallons.
Ammonium sulphate	23.3 pounds.	38.0 pounds.
Surplus gas (debenzolized)	7500 cubic feet.	10,000 cubic feet.
B. T. U. per cubic foot gas	500	560
Total B. T. U.'s in surplus gas	3,750,000	5,600,000
Light oil (benzols)	2.6 gallons.	5.4 gallons.

A comparison in value of by-products on a basis of normal values shows a credit per ton of furnace coke of approximately $1.25 in favor of the high volatile coal.

The fourth high spot in development was the awakening to the fact that, while an increase in the cubical content of an oven tends to a reduction in plant cost and in operating labor due to handling larger units, a decrease in oven width would more than offset this unit size advantage because of absolutely different conditions.

The reason for this becomes apparent with an understanding of the factors involved. Increased length of oven gives increased cubical content, and the ultimate economic length depends on the mechanical and structural limits. Of increased height the same may be said, except that this involves questions of time of contact of volatile products and speed of their flow which modify the advantage and which are yet to be finally worked out.

Increased *oven width* involves an entirely different consideration. Practically all the heat supplied for the coking of the coal mass flows from the two walls toward the centre. This flow of heat depends, to a large extent, on the resistance and temperature, and in the coke oven the average rate of coking depends, of course, on the rate of heat penetration. For example, it becomes apparent at once, in a comparison between a 16-inch oven and a 20-inch oven, that the following is true:

(*a*) With the same temperature of wall the average velocity of coking in the 20-inch oven will be less than in the 16-inch oven, and the time required to coke the 20-inch oven will be more than proportionally greater than the 16-inch oven.

(*b*) To coke the 20-inch oven in the same time as the 16-inch oven, the wall temperature must be increased very markedly.

(*c*) To coke the coal in the two ovens at the same average rate, the wall of the wider oven must be considerably hotter than the narrower one.

(*d*) With the *same wall temperatures*, more coke can be made per day in the narrower oven than in the wide one.

(*e*) To make the same amount of coke per day, the wall temperature in the 16-inch oven would be lower.

Four points are of great value in this connection:

1. Overcoked material is of less value in a furnace than a greener coke.

2. The wider the oven the more overcoked the outside layers will be and the larger the proportion of overcoked material for a given output.

3. The production of by-products is enhanced by reducing the wall temperatures.

4. The life of oven brickwork is increased by being operated at lower temperatures.

The result of this reasoning was the decision, in 1914, to reduce the width of oven from 19¾ inches, average then being built, to 18¼ inches.

Plants of the reduced width are now in operation as follows:

	Ovens
Toledo Furnace Company	94
Youngstown Sheet and Tube Company	204
United Furnace Company	47
River Furnace Company	204

There is no doubt among those who have been acquainted with the wider ovens that the narrower oven has the following distinct advantages:

1. Less sponge in the coke.
2. Better coke from the same coal.
3. As good coke from higher volatile mixtures.
4. Higher yields of tar, ammonia, and benzols.
5. Low temperatures for the same coking velocity.

We shall now consider the fifth high spot in coke oven development; namely, the universal recovery of benzols. This may be laid almost entirely to the war, but partly to the increasing demand for motor fuel. It was the war which furnished the primary inducement to developing this phase of the industry; but the fact that the material might be disposed of advantageously for motor fuel after the demand for explosives would cease had an important bearing in stabilizing the large investments demanded.

Previous to the war comparatively few plants were equipped for benzol recovery; in fact, outside the plants of the Semet Solvay Company, operated for their own account, there was comparatively little benzol extracted, and this was used, for the most part, in enriching illuminating gas. To-day practically every coke oven plant in America has installed this recovery, and

the production in 1917 will be in excess of 40,000,000 gallons, rated as light oil, if continued at the present rate.

While the removal of benzol reduces the heat units in the gas, the loss in this manner is a very small factor, and the return to be secured from the sale of this product is likely to be greater than that secured from the recovery of tar.

One feature of the benzol credit as related to motor fuel is the smallness of the quantity compared with gasoline production, and, since benzol and gasoline are miscible, the utility of benzol will be enhanced by increasing the quantities available.

Experiments recently conducted by a large oil company on its trucks and passenger automobiles proved that not only is benzol more valuable than gasoline as a motor fuel when used straight, but its effective value is increased by being mixed with gasoline. While these experiments are not complete, nevertheless they indicate that a mixture of equal parts of gasoline and benzol gives a value over 16 per cent. greater than that of straight gasoline, which shows 32 per cent. increased value for the benzol half. In 1917 there will be produced in this country over 1,000,000,000 gallons of gasoline, so, while the value of benzol is stabilized, for this reason it cannot be a very great factor in the motor fuel situation. Every means should be taken not only to secure additional quantities from a standpoint of *preparedness*, but from a standpoint of motor fuel supply.

In connection with the value of benzol as a motor fuel there is an interesting fact which may in the future have a very marked influence.

Alcohol is in many quarters looked upon as the ultimate fuel, but it cannot be employed except with less efficiency and with greater difficulties, due to its high hydrogen content. Commercial alcohol and gasoline are not miscible. Alcohol and benzol are miscible and make a most efficient fuel, and, further, *after the addition of benzol to alcohol* the mixture will carry quite a high proportion of gasoline. The future may see benzol as the tie between gasoline and alcohol, permitting a piecing out of the gasoline supply and an introduction of alcohol as a commercial motor fuel.

So much for the introduction of benzol recovery into all coke plants, and for the salient points in coke oven development in America.

We shall now take up a somewhat more detailed study of by-product coke and its use in blast furnaces.

The phenomenal growth of the by-product industry has stimulated a renewed interest in the main product. This interest is due, first, to the recent revolutionizing of ideas regarding the relative values of by-product and beehive coke. The tardy recognition of the fact that by-product coke of a fairly wide range of origin, when properly used in the blast furnace, gives results not merely as good as, but much *superior* to, those obtained from beehive coke, was accompanied by a realization that the limit of efficiency had by no means been reached; that Grüner's "ideal performance"—long the *ne plus ultra* of blast furnace men—was actually being surpassed by many blast furnaces, and that much regarding the question of coke economy still remained to be learned. In the renewed study of the subject that this realization is just beginning to stimulate, we have the inestimable advantage that the by-product coke plants are being located in proximity to, and usually under the same management as, the blast furnaces that they are intended to supply, instead of being placed at the coal mines, long distances away, as was the case with the beehive ovens. Thus the blast furnace operator knows better the sources of the material that he has to use and the conditions under which it was produced, while the coke plant operator can more intelligently regulate the performance of his ovens and the quality of his product, according to the requirements of the furnace. Above all, the combination and coöperation of the two plants result in a regularity of performance that is perhaps more to be desired than any specific quality of material. It is to be hoped that this coöperation may soon be extended to the foundry and other industries using coke as fuel.[1]

It will assist in following the few descriptive studies of coke that we have to present, to give a brief account of the generally accepted theory of the coking process. The development of this theory is due to several German investigators, notably

[1] It is of interest to recall that The Franklin Institute is probably the first scientific organization in the world to go on record in the way of encouraging the utilization of coke in iron manufacture. "In 1835," says Fulton, "The Franklin Institute of Pennsylvania offered a premium of a gold medal to the person who shall manufacture in the United States the greatest quantity of iron from the ore during the year, using no other fuel than bituminous coal or coke, the quantity to be not less than 20 tons."

Muck,[2] Hilgenstock,[3] Rau,[4] and Simmersbach,[5] and it has received such abundant confirmation from every practical standpoint that there can be no question of its soundness.

Let Fig. 1 represent a section across a by-product coke oven

FIG. 1.

FIG. 2.

FIG. 3.

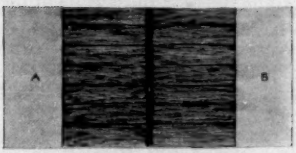


Diagram of the coking process.

immediately after the charge of coal is introduced. The layer of coal next to each wall *A* and *B* is very rapidly heated. A complicated process of destructive distillation begins, and at a

[2] "Chemie der Steinkohle."
[3] *Jour. für Gasbeleuchting*, 45, 1902, p. 617.
[4] *Stahl und Eisen*, 1910, p. 1240.
[5] "Grundlagen der Kokschemie," Berlin, Julius Springer, 1914.

temperature of about 375° to 400° C. the layer becomes soft and pasty. The pasty mass is for a while in a state of violent ebullition, due to the rapid expulsion of its volatile matter, and then rapidly solidifies, the indurated residue retaining the vesicular form and structure of the pasty, foaming stage.

The adjacent layer toward the interior has in the meantime reached the pasty stage, the fusion being assisted by the penetration of some of the soft material forced over from the outer layer. The gases and vapors follow always the line of least resistance and pass through the porous outer layer and up along the wall of the oven instead of forcing their way through the viscous inner portion of the fused layer, and then through the mass of coal. In passing through the highly-heated porous layer, the hydrocarbons undergo a partial secondary decomposition, depositing part of their carbon on the cellular surfaces, just formed, thus building up and strengthening the coke. The coking process is thus to be conceived as involving the formation of a fused zone, and the gradual advance of this zone toward the centre of the oven, the evolved gases and vapors depositing part of their carbon in the vesicular mass left as the zone progresses. The condition of the material in the oven when the coking has fairly well advanced may be represented by Fig. 2. *c* is the portion already coked, *d* is the fused zone merging into an adjacent zone *e*, which, being in a state of incipient fusion, is more viscous. *f* is the uncoked coal.

The actual thickness of the fused zone is probably not over one-half inch. The drop of temperature across this narrow zone is very great, and the interior of the oven remains comparatively cool, even at an advanced stage in the coking process. Simmersbach's experiments[6] on a Koppers oven of 500 mm. (19⅞ inches) mean width, operating on 29 hours' coking time with a final maximum temperature of 1120° C., showed that the temperature in the middle of the oven, 1 metre above the floor, remained about 10° C. for 2.5 hours after charging; then rose to 100° C., and remained at this temperature until 13 hours after charging. At 20 hours the temperature was only 410°.

The rate of advance of the two zones toward the centre of the oven depends principally upon the temperature of the walls

[6] *Stahl und Eisen*, June 14, 1914, p. 954.

(*A*) and (*B*). In present practice, with ovens 18 inches wide and wall temperatures about 1000° C., the average rate is about one-half inch per hour. The initial rate is, however, much more rapid than this, and decreases as the centre of the oven is approached.

As the coking progresses, cracks or joints develop perpendicular to the walls of the oven, thus determining the blocks of coke as they are eventually formed when the oven is discharged.

FIG. 4.

Coke in by-product oven just after removing door.

These cracks form avenues of escape for a large percentage of the gases, hence the amount of deposited carbon is greater in proportion on the surfaces of the blocks than in the interior. Eventually the two zones merge at the centre of the oven (Fig. 3), and, with the practically complete expulsion of the last of the volatile matter, the coking process is finished. There is always a distinct parting in the centre of the oven, so that the length of the blocks is equivalent to about half the width of the oven. Fig. 4 shows a view of the coke as it appears when the door of the

oven is removed. Most of the coke immediately adjacent to the walls of the oven is covered with a skin of carbonized pitch. The true form of the blocks may be seen in a few places where this has been broken away.

Fig. 5 shows a lot of standard by-product coke used on one of the lake furnaces as the material appears on the wharf, just after being run out from the quenching car. Fig. 6 shows a closer view of another typical coke. In this figure the individual

Fig. 5.

Blast-furnace coke, Lake District.

blocks may be seen more distinctly. A few characteristic blocks are shown in Fig. 7. The three smaller pieces in this figure are cross-sections. The end of the block (Fig. 8) that was originally adjacent to the wall of the oven may always be distinguished by its cauliflower-like appearance and dense layers of deposited carbon. We shall designate it as the wall end and shall call the other extremity the centre end, for want of a better term. The structure of the coke towards the centre end is always more open, and occasionally is somewhat spongy.

The shape of the coke is quite characteristic, depending upon the coal from which it was produced, and also, to a considerable extent, upon the method of heat treatment. The coke-oven man classes his product as either "blocky" or "fingery," coke of the former character being preferred. Some typically fingery coke is shown in Fig. 9. As a rule, the coke from coals of over 30 per cent. volatile matter is apt to have a fingery tendency—and this becomes highly pronounced if the coal has a high oxygen

FIG. 6.

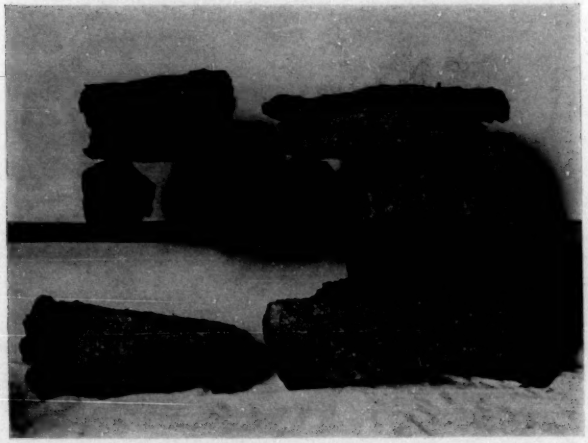
Blast-furnace coke, Atlantic District.

content. By coking such coals very slowly at temperatures somewhat lower than used in ordinary practice, the fingery tendency may be disguised or in many cases entirely eliminated. By disguising it, we mean that the product will actually appear to form large, massive blocks, but these blocks, if closely examined, will be found actually to be bundles of slender pieces more or less firmly cemented together. However, if the heat treatment be very carefully regulated during the coking process—especially in ovens designed and adapted to this particular type of coals—

genuine, firm, blocky coke may be made from many coals usually regarded as producing only the fingery variety.

The size of the blocks is affected to a certain extent by almost all the conditions pertaining to the manufacture of coke. The length is, of course, dependent upon the width of the oven, the average being, on account of shrinkage, a little less than half the width of the oven. The blocks from the top of the oven are usually (especially with high volatile coals) shorter than those from

Fig. 7.



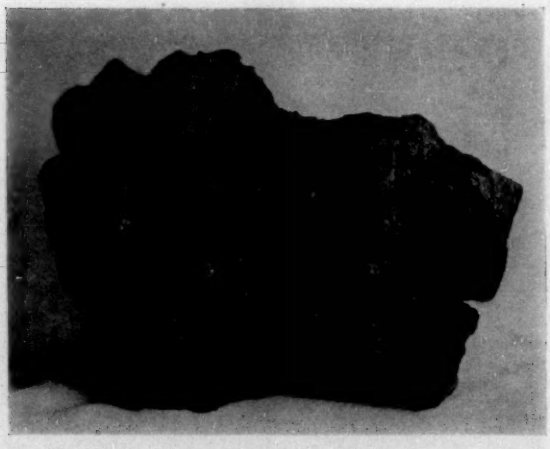
Typical by-product coke.

the bottom. Overcoking and high temperatures tend to produce small-sized coke.

Coming now to an examination of the natural surfaces of the blocks, we may, in the first place, disregard the color as being relatively unimportant. It depends largely upon the method of quenching, and, to some extent, on the quality of the water used. the use of large amounts of water causing a dark color, while with the careful use of a minimum quantity of water a light gray color can always be preserved. The majority of cokes pro-

duced from the standard coking coals rich in hydrocarbon production and low in oxygen have close-textured, even surfaces, with possibly a few narrow, transverse zones of slightly larger cell openings interspersed between the two extremities. Many cokes from coals of the Connellsville (Pa.) type show the same silvery, glossy skin that used to be so much prized in beehive coke. This is probably indicative of a very heavy deposit of

FIG. 8.



Wall end of a block of coke.

carbon, especially favored by slow and uniform evolution of a very rich gas.

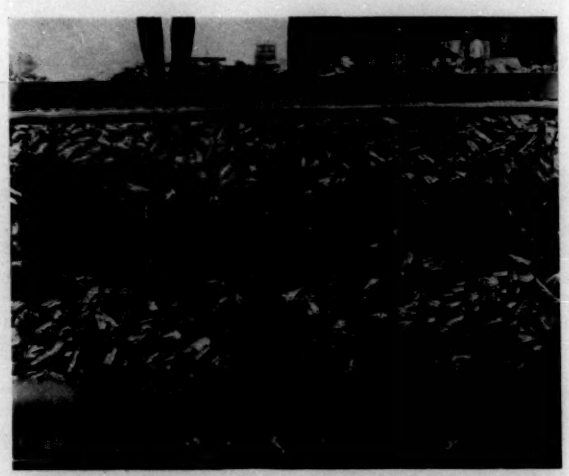
Other cokes, fully equal in value to the above, are characterized by a peculiar shaggy appearance, as if they were covered with blotches of dark moss. This appearance is usually found in cokes produced from mixtures of eastern coking coals with the somewhat more highly oxygenated coals of the central field. Oddly enough, both types of coal usually make smooth coke if carbonized separately.

Certain cokes present transverse pebbly seams—usually not

more than two or three. These seams are very narrow and quite coherent, and may be shown to be composed of small globules of quite pure carbon, with no apparent cellular structure. This phenomenon again appears to be characteristic of the more highly oxygenated coals.

The surfaces always show more or less transverse and longitudinal cracks, significantly at right angles—either parallel or per-

Fig. 9.



Fingery coke and sponge (Colorado coal).

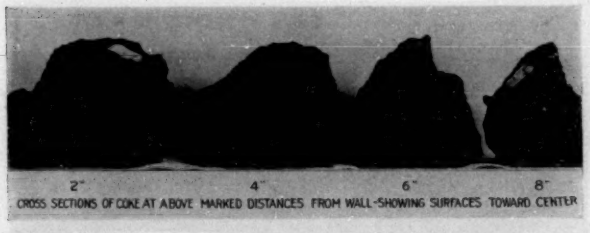
pendicular to the wall of the oven. Naturally these are an element of weakness, and their presence to an excessive degree is one of the surest "first-hand" indications of an inferior grade of coke that we have. The amount of fracturing can be controlled to a surprising extent by proper method of heat treatment.

By breaking a piece of coke and examining the fresh surfaces we find revealed the cellular structure that is characteristic of all cokes and which cannot be seen in its true development simply by inspecting the dense natural surfaces. No definition of coke

is complete that does not take this cellular structure into account.

The usual way—and the easiest—to examine the cell structure is to break a piece of coke crosswise and note the appearance of the fresh surfaces. Great care must, however, be taken, in comparing one coke with another by this method, to break the

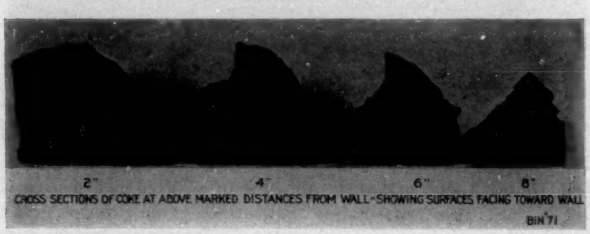
FIG. 10.



CROSS SECTIONS OF COKE AT ABOVE MARKED DISTANCES FROM WALL-SHOWING SURFACES TOWARD CENTER

pieces at approximately the same distance from the wall end, since the size of the cells is apt to increase considerably from the wall to the centre. Oddly enough, in many cokes there is a characteristic difference in the two surfaces of a break. No matter where the piece is fractured, the surface on the wall side has

FIG. 11.



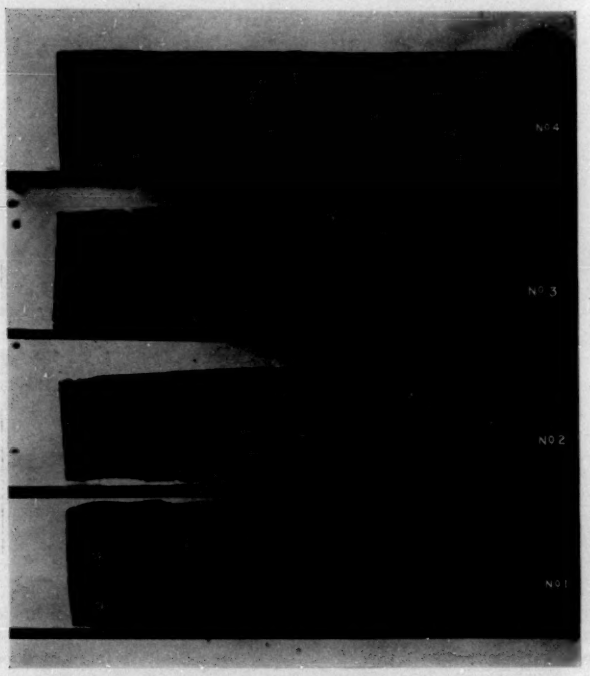
CROSS SECTIONS OF COKE AT ABOVE MARKED DISTANCES FROM WALL-SHOWING SURFACES FACING TOWARD WALL
BIN 71

almost a granular appearance, with a steel-gray lustre and well-defined cell openings. The opposite surface (*i.e.*, looking toward the centre of the oven) has a characteristic graphitic lustre, with the cell openings flatter and possibly not so sharply defined.

Although this difference is rather hard to depict photographic-

ally in a satisfactory manner, we have attempted to do so in Figs. 10 and 11, which will also show the variation of the sizes of cells from wall and to centre. The sections have been made with a 1/16-inch emery wheel at 2, 4, and 6 inches from the wall

Fig. 12.



Standards for gauging cell structure.

end of the same block of coke. (This is a standard blast-furnace coke made from a mixture of West Virginia and Pennsylvania coals, and is the same as shown in Fig. 16.) Fig. 10 shows the surfaces facing the centre end of Fig. 11 shows the corre-

sponding surfaces facing the wall; *i.e.*, as one looks at Fig. 9 he is looking toward the wall, and *vice versa* with Fig. 10.

For any accurate comparison of the cell structure of different cokes we prefer to make longitudinal sections with a thin emery wheel—such sections as are shown in Figs. 13 to 21. If this is done, the danger of confusing sections made at different distances from the wall will be largely eliminated. It must be mentioned that *breaking* a piece of coke longitudinally so as to re-

FIG. 13.

veal the real cell structure is a decidedly difficult matter. Almost always the break will be found to be made along the plane of a natural longitudinal fracture, and the exposed surfaces will be found to be covered with deposited carbon.

Great importance has been attributed to the cell structure of coke by all authorities on the subject, and especially by blast-furnace operators, and yet the subject is very poorly defined and no standards of comparison have been established. We have recently begun the use of a simple system, analogous to the scale

Fig. 14.

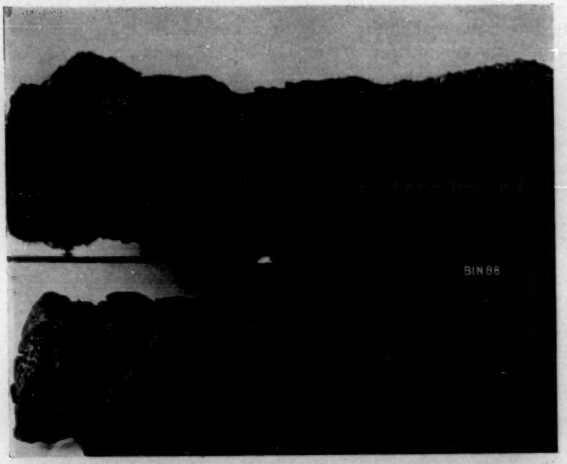
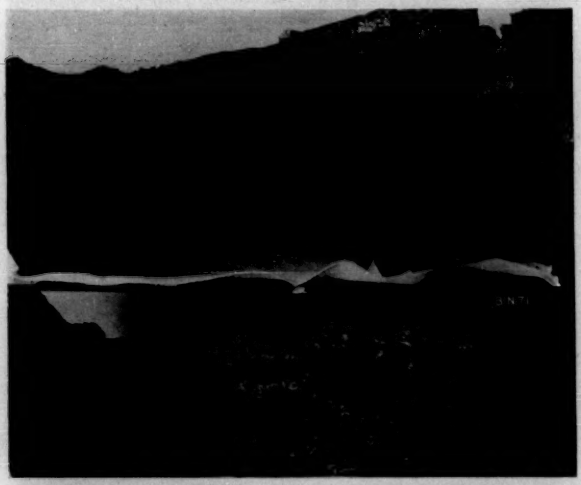


Fig. 15.

of hardness used in the study of minerals, which we hope may come into general favor. At present we employ a set of four standards, shown in Fig. 12. These are all longitudinal sections, cut from blocks of typically different coke. The sections are the same length, and each is cut beginning 1½ inches from the wall end. The sections are numbered 1 to 4 in order of increasing cell size. With such a set of standards it is easy to grade any coke according to its cell structure, and the grading will

FIG. 16.



convey a much more definite idea than the loose terms of "dense," "close," "rather close," "fairly open," "medium," etc., that have hitherto been used. No term in our usual technical vocabularies has been so overworked as the word "*medium*," as applied to the cell structure of coke.

In addition to grading cokes according to the size of the cells, we may also classify them as regular or irregular in cell structure. The standards would all be considered as regular in structure. This does not mean at all that the cells are of the

Fig. 17.

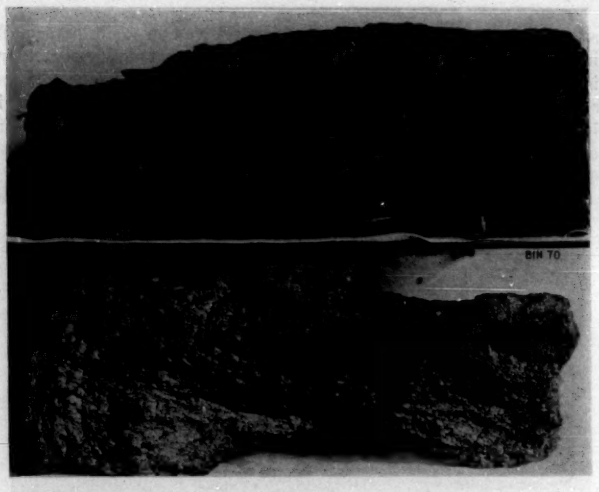
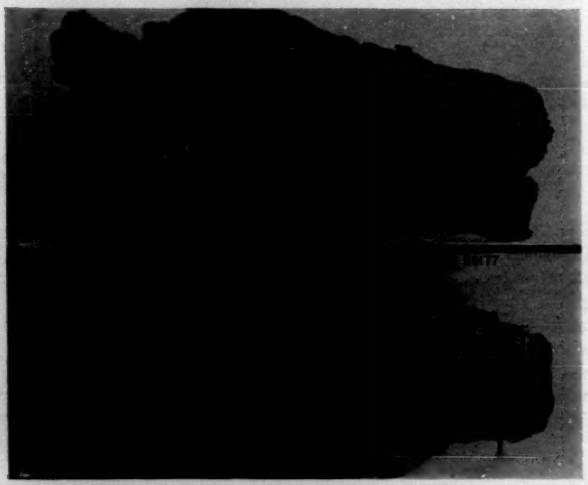


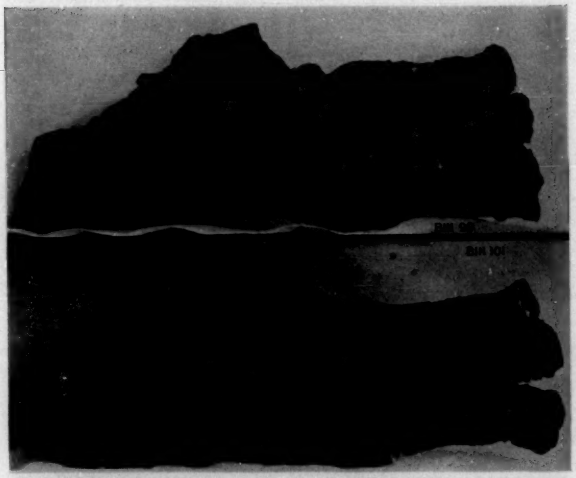
Fig. 18.



same size, but their general arrangement gives an easily perceived impression of regularity. What we mean by irregular structure is illustrated by the sections shown in Figs. 13 and 14. This sort of coke has alternate patches of close and open texture, and is frequently produced by the more highly oxygenated class of coking coals, as well as by mixtures of coals having decidedly different characteristics.

It might possibly be thought now that an interesting table

FIG. 19.



could be prepared grading the cell structure of cokes produced from various typical coals. Such a table would be well-nigh valueless, unless the data were carefully qualified by details regarding preliminary treatment of each coal, dimensions of ovens, temperatures, coking time, and several other factors, each of which plays a part in the development of cell structure. It may be more profitable to show a few sections of different cokes that have given successful results in blast-furnace and foundry practice in various parts of the country. Figs. 13 to 21, inclusive,

Fig. 20.

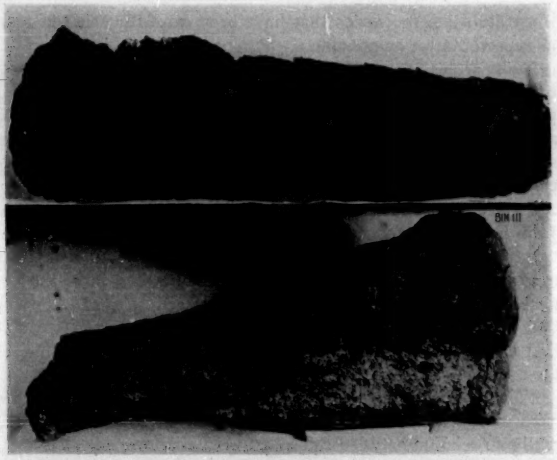
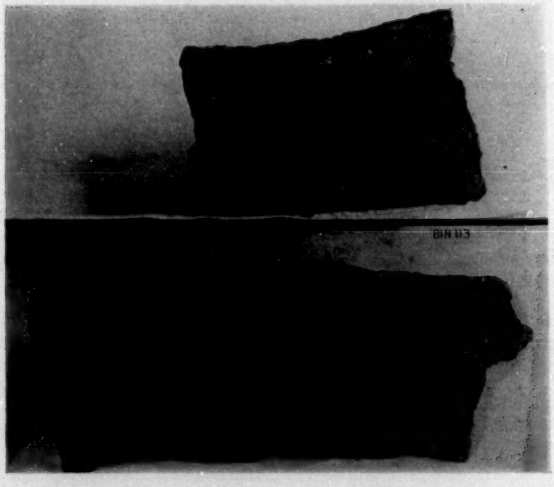


Fig. 21.



illustrate some specimens that have been carefully selected to be as representative as possible.

Sometimes too much reliance is placed in the determination of the specific gravity and porosity of coke. Figures as to porosity or the percentage of cell space in the total volume of coke are almost valueless, unless supplemented by an examination of the actual size of cells and thickness of cell walls. A coke of close texture and thin walls may have the same percentage of cell space as one having large cells and relatively thick walls. As John Fulton [1] the pioneer investigator of coke, said, 34 years ago: "Mere cellular space . . . cannot be used as an element in the practical determination of the value of cokes for blast-furnace use. Furnace gases cannot act on cell spaces; they can only act on exposed surfaces." It is the cell walls and surfaces that are the most important. Cell space and porosity, which is the measure of it, are merely incidental.

The following table of specific gravities and porosities of the coke specimens illustrated in this paper will show that there is really no relation between cell structure and porosity:

TABLE III.

Cell grading	Figure	Apparent specific gravity	True specific gravity	Porosity
1 (Standard)	12	1.097	1.917	42.8
1	14	0.924	2.006	53.7
1.5	13	0.974	1.891	48.5
2 (Standard)	12	1.007	2.028	50.4
2	17	1.138	1.948	41.6
2	18	0.997	1.979	49.6
2.5	15	0.857	1.979	56.7
3 (Standard)	12	1.071	1.831	41.6
3	20	1.053	1.917	45.1
3	21	0.854	1.862	54.1
4 (Standard)	12	0.943	1.988	52.6
4	16	0.943	1.988	52.6
4	19	0.917	1.921	52.3

For ordinary purposes in grading cell structure magnification is unnecessary. Photographic enlargement gives some interesting information as to the character of the cell walls. Figs. 22, 23, 24, and 25 show portions of standards Nos. 1, 2, 3, and 4,

[1] *Bull. Am. Inst. Min. Eng.*, October, 1883.

respectively, each enlarged 10 times. There is considerable apparent irregularity of cell diameter, due to the fact that the cells are cut in different planes, but the comparison of the four types of coke is fairly good.

In passing from this subject of the examination of coke sections we should take occasion to point out the interesting field that is here open for the application of petrographic methods to an exhaustive investigation of the material. The actual chemi-

Fig. 22.

Standard No. 1, enlarged 10 diameters.

cal and physical state of the carbon produced from various coals under various conditions is an important matter from a practical standpoint. Differences in the true specific gravity of coke are frequently found that cannot be explained by variation in the content of inorganic matter. The actual condition of this inorganic matter after carbonization, the amount of reduction of the various oxides, the possible effect of the finely-disseminated mineral matter in strengthening or weakening the cell walls are

all very important. Inorganic matter does not necessarily constitute an element of weakness. Large particles, especially if segregated, are injurious, but finely-divided mineral matter may actually strengthen the cell walls. High-ash cokes are frequently stronger than low-ash cokes from the same kind of coal. Some experiments in washing and coking coals of moderate ash content have shown that where the original coal gave a strong coke, the washed coal gave a weaker coke, the difference being un-

FIG. 23.

Standard No. 2, enlarged 10 diameters.

doubtedly due, to some extent, to the removal of some of the mineral matter, although the high moisture content of the washed coal might have had some effect. Simmersbach gives some evidence to show that iron present in combination with carbon and silicon, and silicon present as a silicon carbide, may be the cause of the remarkable hardness of some coke.

Studies of this character will, however, be largely of academic interest unless correlated with studies of the behavior of differ-

ent types of coke in the blast furnace and in other types of apparatus in which the material is used. Let us choose the blast furnace for consideration here on account of its tremendous industrial importance.

There is at present some disagreement among blast-furnace men as to the exact function of the coke in the most efficient and economical reduction of iron ore. The majority probably still

Fig. 24.

Standard No. 3, enlarged 10 diameters.

accept Grüner's theory of ideal working, viz. (as stated by Richards[8]), "All the carbon burnt in the furnace should first be oxidized at the tuyères to CO, and all reduction of oxides above the tuyères should be caused by CO, which thus becomes CO_2." It is well known that the reduction of iron oxide by carbon monoxide is the most efficient from the standpoint of heat economy. Richards, however, has pointed out that the direct reduction of iron oxide by carbon is three times as efficient from

[8] "Metallurgical and Chemical Calculations," p. 248.

the standpoint of carbon required as the indirect reduction, and says:

"The ordinary furnace produces at the tuyères, in order to get heat enough to melt down the charges, more CO gas than is needed to abstract all the oxygen from the charges; under these conditions it is uneconomical to oxidize any carbon at all above the tuyères. The exceptional furnace, because of pure ores, small amount of slag, pure fuel, high temperature of blast, or

FIG. 25.

Standard No. 4, enlarged 10 diameters.

dry blast, gives heat enough at the tuyères to melt down the charges without producing enough CO gas to reduce all the charges; under these conditions, more or less reduction is effected by solid carbon and with the greatest economy in quantity of carbon required in the furnace."

About a year ago Mr. H. P. Howland prepared an interesting paper,[9] entitled "Calculations with Reference to the Use of Car-

[9] *Bull. Am. Inst. Min. Eng.*, March, 1916, p. 627.

bon in Modern American Blast Furnaces," calling attention to the fact that many furnaces are actually operating with higher economy of coke than would be calculated from Grüner's theory; in fact, his calculations on the performance of 26 furnaces seem to show that what Richards regarded as the exceptional furnace is the rule rather than the exception in modern practice.

Howland's tabulation of data on these 26 furnaces is so interesting and pertinent to the subject that we are reproducing a portion of it herewith:

Furnace No.	Pound coke per ton iron.	Tons iron per day.	Carbon in coke per cent.	Kind of method of manufacture.	Coke operation.	Total charged.	Gasified in furnace.	Gasified at tuyeres.	Per cent. total carbon.	Per cent. gasified carbon.
1	2,615	301	86.3	BH	Stonega	2,254	2110	1868	82.8	88.6
2	2,551	272	84.4	BP	Solvay	2,153	2049	1751	81.4	85.6
3	2,472	482	86.1	BH	Conn.	2,128	1906	1728	81.2	86.6
4	2,247	450	87.1	BH	Conn.	1,957	1846	1605	82.0	87.0
5	2,198	499	86.9	BH	Conn.	1,908	1810	1494	78.7	82.6
6	2,123	541	88.3	BH	Conn.	1,875	1764	1498	79.8	84.9
7	2,115	360	84.3	BP	Solvay	1,782	1683	1427	80.1	84.8
8	1,996	490	86.3	BP	Koppers	1,722	1611	1298	75.4	80.6
9	1,936	376	85.7	BP	Solvay	1,659	1557	1305	78.8	83.7
10	1,905	393	88.7	BP	Solvay	1,690	1575	1252	74.1	79.5
11	1,901	517	85.5	BP	Koppers	1,625	1524	1280	78.8	84.1
12	1,863	504	86.6	BP	Koppers	1,614	1513	1230	76.2	81.3
13	1,780	426	84.9	BP	Koppers	1,511	1414	1124	74.4	79.5
14	1,742	503	84.6	BP	Koppers	1,474	1382	1133	76.9	82.0
15	1,716	542	87.1	BH	Benham	1,494	1396	1194	80.0	87.0
16	1,715	585	84.6	BP	Koppers	1,451	1357	1114	76.7	82.2
17	1,702	543	87.5	BP	Koppers	1,490	1388	1130	75.9	81.5
18	1,699	572	87.0	BP	Koppers	1,479	1387	1155	78.2	83.4
19	1,673	580	88.6	BH	Benham	1,482	1384	1182	79.9	85.0
20	1,658	590	88.3	BH	Benham	1,464	1366	1182	80.8	86.5
21	1,636	442	89.5	BP	Koppers	1,463	1369	1124	76.8	82.1
22	1,635	503	88.5	BH	Benham	1,447	1349	1124	77.7	83.4
23	1,624	592	87.3	BH	Benham	1,417	1317	1118	79.0	85.0
24	1,623	457	89.6	BP	Koppers	1,454	1360	1090	75.0	80.2
25	1,589	608	88.3	BH	Benham	1,403	1307	1100	78.5	84.2
26	1,584	466	89.2	BP	Koppers	1,413	1324	1057	74.8	79.9

NOTES.—BH = Beehive. BP = By-product. Conn. = Connellsville.

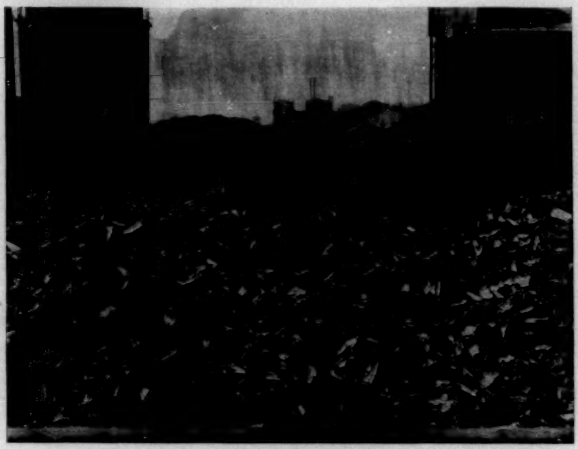
Note incidentally the performance of the once-despised by-product coke in modern practice. Of the 19 furnaces using less than a ton of coke per ton of pig iron, 13 are burning by-product coke and 6 beehive coke.

Howland calculates that all the furnaces burning less than 1350 pounds of carbon at the tuyères are not making enough CO to reduce all the Fe_2O_3 and hence some of the latter must be reduced directly by carbon. He concludes:

"It seems clear, therefore, that in low-coke furnaces one of the most important, if not the most important function of the carbon burned at the tuyères is to produce heat to enable the carrying on of the direct reduction, rather than to produce CO for indirect reduction.

"On this basis, it becomes very essential that our carbon shall burn instantaneously to CO in order that the resulting heat may be localized where needed. This should not be a question of seconds, but of a fraction of a second. If our carbon is of such a nature that this burning to CO is a comparatively long process, more of it will be required than of the quick-burning carbon

FIG. 26.



Coke from straight high volatile coal, showing sponge.

in order to obtain the same concentration of heat at the desired point.

"We would, therefore, say that the most desirable thing about a coke is that quality in the carbon which will allow of its being instantaneously burned to CO and thus result in the maximum concentration of heat where needed."

W. H. Blauvelt, in a discussion of Howland's paper,[10] says:

"In studying the combustion of coke in the furnace, it is clear that the production of the maximum quantity of heat is not

[10] *Bull. Am. Inst. Min. Eng.*, October, 1916.

of the first importance in blast furnace operation, or in the utilization of the fuel charged into the furnace. To my mind, the production of a high thermal head at the tuyères is of the first importance, and the best coke is that which reaches the tuyères in proper condition to produce the highest temperature at the tuyères, and in just sufficient quantity to do the amount of work

Fig. 27.

Coke from same coal as Fig. 26, with 20 per cent. Pocahontas.

required there under the conditions produced by this maximum temperature. The combustion of a much larger amount of fuel at the tuyères, under conditions that will fall short of producing the highest possible temperature, cannot produce as good results, either in fuel economy or output. . . . Nothing is more fatal to obtaining the highest temperature than an excess of combustion. In the blast furnace an excess of air dilutes and cools the products of combustion, reducing the maximum thermal head at the tuyères, and the larger volume carries the high temperature zone too high in the furnace. . . . It will probably be generally admitted that furnace coke should be of nearly uni-

form size, and many furnace managers are eliminating all coke below ¾ inch and above 4 or 4½ inches; also, that the best coke is that which is sufficiently strong to resist undue abrasion and crumbling by attrition with the stock, and of an open porous structure that will permit the most rapid combustion when it reaches the tuyères. Many large users agree that the coke should never be overcoked beyond the point of producing a sufficiently strong structure, as overcoking quickly reduces the combustibility.

FIG. 28.

90 per cent. high volatile coal + 10 per cent. Pocahontas.

"If Grüner's ideal gives the best furnace operation, we should want a coke that is resistant to the oxygen in the ore, but easily combustible at the tuyères, which is a contradiction of qualities. If my argument is correct, that the furnace man wants the greatest thermal head at the tuyères rather than the production of the greatest quantity of heat in the furnace as a whole, then he is willing to sacrifice some coke by solution in the oxidizing gases in the upper part of the furnace, provided he can obtain a sufficient quantity of coke at the tuyères, of a quality that will

permit rapid combustion with the minimum amount of air, thereby giving him the maximum thermal head."

The desirability of the condition which Blauvelt aptly terms "a high thermal head" in the zone of the tuyères will be readily granted even by those who adhere to Grüner's theory. This condition should be attained even at a sacrifice of some carbon by solution loss ($CO_2 + C = 2CO$), and we are of the opinion that the importance of this solution loss is frequently overestimated.

Fig. 29.

70 per cent. high volatile + 30 per cent. Pocahontas.

Most laboratory experiments made to determine the loss undergone by different cokes have been of little value, because they have been mostly made with pulverized samples, so that their original physical condition has been greatly altered.

We have lately tested the resistance of a number of cokes to the action of CO_2 at temperatures of 800° and 900° C., and find the loss of coke pulverized to 40 mesh to be very much greater than the same coke prepared in small test pieces, ⅜ inch by ⅜ inch by 1½ inches, so as to retain the original structure.

As furnace conditions are better understood the possibility of the use of coke of a wider instead of a more restricted range of quality will become better recognized, with the express limitation that the supply for each furnace must always be absolutely uniform in quality. This requirement of uniformity cannot be too strongly emphasized, and it is almost equally necessary for the proper operation of the coke plant as the blast furnace; but this does not mean that there is one standard grade of coke to which all plants should conform so far as possible. As a matter

FIG. 30.

60 per cent. high volatile + 40 per cent. Pocahontas.

of fact, the range of cokes that successfully qualify in practical operation is continually being extended, through necessity of one sort or another, with little general realization of the fact. In Figs. 13 to 22 we have already shown the cell structure of some cokes that are giving good results in different American blast furnaces, and the difference is fairly remarkable.

However, for each kind of coke there is evidently some limit-

ing size for efficient service, *i.e.*, just large enough to offer such a minimum surface of attack for CO_2 that the loss on this account is negligible, and small enough so that complete combustion may be effected in a minimum of time at the tuyères. Hardness of body is usually—though possibly not necessarily—proportional to the resistance of a given coke to oxidation by CO_2 or oxygen. The harder grades of coke should be used in smaller sizes—and this is a compensation automatically provided to some extent by

Fig. 31.

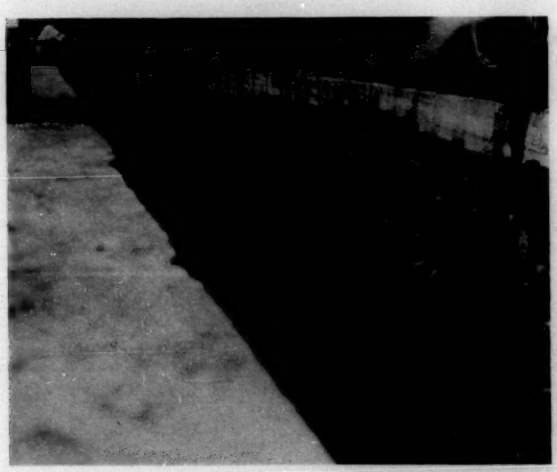
Coke from Colorado coal, showing sponge.

the operation of the by-product oven. Similarly, cokes of close cell structure are more resistant to oxidation, but this may be offset to a large extent by softness. The coke of more open cell structure will probably require less rigid attention to sizing than the denser coke. The important thing is to determine the practical limits of these elements of size, hardness, and cell structure. It may be found that a coke of such structure as No. 1 of our scale may be unsuitable, no matter what may be its size or

softness; but this ought to be proved by actual test and not taken for granted.

These considerations are of the utmost importance and encouragement to the coke-oven man, because, with a reasonable choice of coal, his control over the quality of his coke is almost unlimited, and, even with a very restricted source of supply, the possibilities of conforming to the desired standard by proper oven construction and regulation are still remarkably great. We

FIG. 32.



Coke from same coal as Fig. 31, properly made.

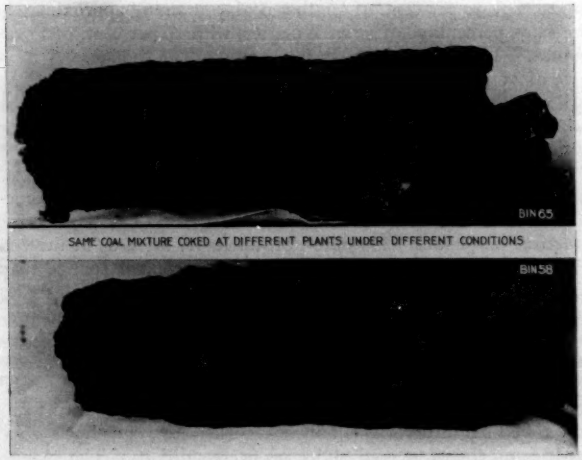
propose to conclude this paper by showing two or three examples of what can be accomplished in the way of control of this sort.

One proposition that frequently presents itself is that of eliminating sponge. Sponge is a characteristic honeycombed mass formed in the centre of rich volatile matter. It seems to be caused by an excess of pitchy material moving along with the fused zone in the coking process, and finally accumulating in the centre of the oven, where it is eventually gasified, with the pro-

duction of this light porous material. Sometimes this sponge is found in loose, detached masses scattered all over the coke as it lies on the wharf after quenching, or, again, it may be found adhering very closely to the ends of the pieces of coke, and sometimes blending, without any clear line of demarcation, into the body of the coke itself.

Although the amount of this sponge often appears to be very large, it is so bulky that its actual percentage by weight is small.

Fig. 33.



In one case where the amount of sponge seemed to be very large it was actually found that it amounted to 1.65 per cent. of the total coke. Small amounts of sponge probably do no harm, most of the material being soon broken up in the operations of handling the coke, but the presence of the material undoubtedly occasions a certain loss of carbon, and so we usually try to get rid of it. The customary remedy—and one that always works—is to mix with the high volatile coal sufficient low volatile coal which has the effect of absorbing the excess of bituminous material and

eliminating the conditions of sponge formation. Pocahontas coal is the standard low volatile coal that is employed by many of our plants. It is to be noted that different coals require considerably different percentages of Pocahontas coal to completely eliminate the sponge. Fig. 26 shows a coke from unmixed high volatile coal (about 34 per cent. volatile matter). A large amount of sponge is readily apparent. Fig. 27 shows the coke from a mixture containing 80 per cent. of this same coal with 20 per cent. of Pocahontas. The sponge is entirely eliminated and the structure of the coke improved. Fig. 28 shows coke made from a mixture of 90 per cent. of another coal, containing approximately the same percentage of volatile matter, with 10 per cent. of Pocahontas. This shows a fairly large amount of sponge. A mixture of 70 per cent. of this coal with 30 per cent. of Pocahontas still produces some sponge (Fig. 29), and it required as much as 40 per cent. Pocahontas (Fig. 30) to eliminate the sponge entirely.

Frequently it is too expensive a proposition to buy low volatile coal for the sake of eliminating a little sponge, and sometimes the low volatile coal may be altogether inaccessible for practical purposes. This does not, however, leave us at the end of our resources. By proper methods of control sponge may be eliminated from a wide variety of coals that produce it under ordinary conditions. If the oven is correctly designed and proportioned, and the temperature and coking time carefully regulated, very satisfactory results may be obtained without the necessity of making a special coal mixture. Fig. 31 shows the coke from one coal which was made in a type of oven unsuited to it, and coked at unfavorable temperatures. Fig. 32 shows coke made from the same coal under proper conditions. The sponge has been entirely eliminated.

Occasionally one of the most difficult problems to be overcome is that of too great density of cell structure. Here, again, we can approach the problem in two ways: one, by mixing in one or more other coals that have a tendency to the production of a more open cell structure, and the other way by suitable preliminary preparation of the coal, careful heat control, and special design of the oven. Fig. 33 shows coke made from the same coal mixture coked at different plants under different conditions. The dense coke shown in the lower part of the figure was greatly im-

proved upon when the nature of the coal was better understood, and the excellent product shown in the upper part of the figure was then made when the coal was treated in the right kind of ovens and under proper conditions.

To insure the best results, a special study must be made of each kind of coal that it is proposed to use, and it would be well, in all cases where a new plant is contemplated, to make this study previous to a design of the plant, because the results may suggest some necessary changes in design that would not otherwise be foreseen.

Notes on the Merchant Submarine Deutschland. Anon. (*Scientific American*, vol. cxvi, No. 6, p. 151, February 10, 1917.)—The policy of secrecy which the owners of the merchant submarine *Deutschland* have followed was suspended in the case of the marine artist, Mr. Henry Reuterdahl, when he was permitted to make sketches of the interior. The following notes are based on observations made by Mr. Reuterdahl during his several hours' visit aboard the vessel:

The *Deutschland* is 230 feet in length and is built on the usual system of a circular hull proper, with what might be called an enlarged false hull outside of this. The beam of the hull proper is 17 feet; the full beam of the ship, out to out, is about thirty feet. She is driven by Diesel engines developing 1200 horsepower. The engines have six cylinders and are arranged two on each shaft. The speed on the surface is 14 knots, and submerged 7½ knots. The time consumed in submerging from surface conditions is two minutes. According to Captain Koenig, the total distance run under the submerged condition on the last trip from Germany was 180 miles. American shipping men and naval architects estimate her cargo capacity at 750 tons; according to Captain Koenig, it is 1000 tons. The entire crew, with officers, consists of 29 men.

The conning tower, according to Mr. Reuterdahl, is superior to the type used on our submarines. It carries no loose gear (collapsible surface material) which must be removed previous to diving. The *Deutschland*, like all the later German submarines, is always ready for submergence. The removal of the repeater compass in the conning tower and closing the hatch are all that is necessary. Steering is done from the conning tower, where large ports give clear all-round vision. The German conning towers are large enough to hold four men. When the vessel is submerging, the conning tower is cut off by closing a hatch between it and the interior.

The periscopes, of which there are two, are of great power and remarkable clarity, and in these respects are superior to American periscopes. The periscope in the conning tower is hoisted and

lowered electrically; that in the operating compartment is hoisted by a chain-drive operated by hand. None of our own submarines have housing periscopes. The *Deutschland's* periscopes, it is stated by Mr. Reuterdahl, are of much greater efficiency than those on our submarines, and the difference in clarity of vision is something that must be tested to be appreciated.

The principal arrangements for air control and the working of the various tanks are about the same as in the American navy. Those American officers who visited the *Deutschland* were impressed with the high-class workmanship apparent, particularly of the engines and air compressors. There is nothing about the vessel to indicate that it was built during the rush of war time: every part is as carefully finished as would be expected in normal conditions. A peculiarity of construction is that there is no ventilation cowl or funnel to supply air for the Diesel engines. By an ingenious method the conning tower is so arranged that air vents open and close automatically the moment the ship emerges or submerges. The deck is flush and clear of gear of any kind, pockets being provided for the reception of masts, anchors, etc., the former being raised and lowered by quadrants at their lower ends operated by electric motors. A small lifeboat is secured to the superstructure.

A Bibliography of Alloys. C. ESTES. (*Metallurgical and Chemical Engineering*, vol. xvi, No. 5, p. 273, March 1, 1917.)—The study of alloys in a systematic way began in the latter part of the nineteenth century, coincident with the introduction of the pyrometer and the microscopic examination of metals. The introduction of these instruments made possible a much more exhaustive study of the equilibrium diagrams of alloys. Because of the many requirements for alloys with special properties, a complete systematic study of the equilibrium diagrams of alloys should include at least the following investigations for each member of the series: (1) Thermal equilibrium, (2) thermal expansion, (3) thermo-electric force, (4) molecular volume, (5) density, (6) hardness, (7) tensile strength, (8) ductility, (9) electrical conductivity, (10) solution tension, (11) magnetic susceptibility, (12) separation and identification of compounds, (13) microscopical examination, (14) X-ray examination, (15) optical rotation of polarized light from polished surfaces, (16) photo-electric effect, and possibly others.

Various investigators have studied more or less completely practically all of the binary systems of the common metals and a great many of the rarer metals; also about sixty ternary systems and several quarternary systems. A chart of the binary systems investigated is given, immediately followed by a list of references to each system. Separate lists are given for ternary and quartenary systems. The chart is a convenient coördinate arrangement of the metals, opposite any pair of which a key number to the reference list may be found.

THE ELECTRIC STRENGTH OF AIR AND METHODS OF MEASURING HIGH VOLTAGE.*

BY

J. B. WHITEHEAD, E.E., Ph.D.,

Professor of Electrical Engineering, Johns Hopkins University, Baltimore, Md.

AIR AS AN INSULATOR.

Not only is air a good insulator, but it is one of the very best. It is universally used as such. Practically every electric circuit relies to a greater or less extent upon the insulating properties of the air. The properties of air which make it so valuable as an insulator are its low specific inductive capacity, its very high resistance and its high electric strength or resistance to puncture. Its specific inductive capacity is practically as low as that of any other material and differs very little from that corresponding to the ether. Its ohmic resistance for many years was assumed to be infinite, although we now know from the rate of leak of a charged conductor that it really has an extremely small specific conductivity.

Although the electric strength, or resistance to rupture, of the air was for many years sufficient for all the requirements of electrical engineers, a limit has recently been reached. As voltages for long distance transmission of power have been raised to higher and higher values, it has been found that the air in the neighborhood of the wires breaks down. The phenomenon is visible in the dark as a glow around the wire and is known as the "corona." The glow or brush discharge is confined to the region close to the wire, where the electric intensity is higher than at more distant points. The phenomenon is accompanied by energy loss and this reduces the efficiency of a transmission line.

The value of an electric field at which a break-down of air occurs, and the type of discharge, that is whether spark or corona, depends largely on the shape and size of the electric terminals. Sparks will pass between parallel plates at a field intensity of

* Presented at a joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held Thursday, November 23, 1916.

about 32 kv/cm. Between needle points, spheres and other forms of terminal, the relation of break-down voltage to separation is not regular, and different values of average break-down intensity are met. In these cases the intensity or voltage gradient varies from point to point and the question of break-down seems to involve a relation between the intensity and the volume of the air subjected to this intensity. The matter is further complicated by the fact that the air may be only partially ruptured, forming a brush discharge as observed around needle points and in the corona.

For the reasons mentioned above, simple and symmetrical forms of electrode must be chosen for the experimental study of the electric strength of air. Indeed, only one or two forms of electrode are available. Parallel plates were used by many early experimenters and led to the following law, connecting the separation of the plates X, in centimeters, with the break-down voltage V, in kilovolts.

$$V = 1.35 + 30X \qquad (1)$$

This law, however, has never been utilized by engineers as a means of measuring voltage, due to the limited range over which it has been tested and to the difficulties of constructing parallel plates free from sharp edges and from disturbance by surrounding objects.

THE LAW OF CORONA.

By far the most uniform and constant example of the electric break-down of air is the corona on a clean round wire located axially in an outer cylinder forming the opposite electrode. Under given conditions of temperature and pressure, the critical or corona forming voltage in this apparatus repeats itself in successive observations, with a maximum inaccuracy of a fraction of 1 per cent. Moreover, the arrangement lends itself readily to variation of conditions, and experiments with it have led to the law connecting the critical or corona forming electric intensity—E, in kilovolts per centimeter, with the radius of the wire r, in centimeters.

$$E = 32\left(\delta + .296\sqrt{\frac{\delta}{r}}\right) kv/cm \qquad (2)$$

The quantity δ is known as the "density factor" and has the value

$$= \frac{3.92p}{273+t} \qquad (3)$$

in which p is the pressure of the air in cm. of mercury and t is the temperature, Centigrade. It will be noted, therefore, that at standard conditions δ is equal to unity. The corona *voltage* for any combination of size of central wire and outer cylinder, is calculated from the critical value of E (formula (2)), and the radii of wire and outer cylinder, by well-known relation.

The remarkable constancy and accuracy with which the corona voltage occurs, suggests that it should be a valuable means for studying the nature of the structure of the air. So far, however, it has been practically neglected by experimental physicists. Nearly all of the enormous amount of investigation of the electric properties of the air has been conducted at very low pressures, due to the greatly increased conductivity in that region. The impression has seemed to prevail that, owing to the density of ordinary air, electric and other phenomena are erratic and not suitable for accurate study at atmospheric pressure. The discrete ions of low pressure, which lend themselves so favorably to the development of theory, are supposed to submerge themselves into irregular aggregates at high pressure, thus masking their motion and behavior. The present accepted theory of gaseous conduction, due to Thomson and Townsend, is based wholly on phenomena at low pressures. If this theory is correct, it should explain the clear cut phenomenon of corona and thus secure further valuable support for itself. So far, however, the connection of corona with theory, hangs on the slender thread of one discussion by Townsend.

RELATION OF CORONA TO IONIZATION THEORY.

It will be remembered that the theory of gaseous conduction, as developed by Thomson [1] and Townsend [2] on the substructure of the kinetic theory of gases, conceives the current in a gas to be carried by ions or charged particles of gas. These particles are the negative electron, positively and negatively charged single molecules, or aggregates of molecules with charges of varying magnitude. A break-down or spark-over is due to the progressive generation in the gas of new ions formed from neutral

molecules by impact of other ions moving with sufficiently high velocity in the electric field. This conception, first due to Thomson, has been elaborately developed by Townsend under the name "Ionization by Collision."

The single effort to bring corona phenomena into accord with the theory of ionization by collision is also due to Townsend.[3] He assumes that corona is a form of spark discharge and obeys the law of formula (1). Since the observed laws of spark-discharge between parallel plates are in accord with the theory of ionization, so also must corona be in accord with that theory. The assumption enables him to develop theoretically, the relation shown in formula (2), briefly as follows:

With increasing voltage, the diameter of corona increases, and at such a rate that the electric intensity at the outer boundary is always equal to 30 kv/cm., the minimum sparking intensity for air between parallel plates. The mean value between 30 and the electric intensity at the surface of the wire is then substituted for V in formula (1), for the sparking distance between plates, where X is now the radial thickness of the corona. This leads at once to the simple relation between the critical intensity and diameter of the wire first shown by the results of the writer and expressed by formula (2); when δ is taken as unity that is for standard atmospheric conditions.

The influence of temperature and pressure is added by theoretical deduction from the ionization theory that for a round wire in a cylinder the product of radius of wire and pressure is a function of the product of radius of wire and critical electrical intensity, or

$$ap = f(aX) \qquad (4)$$

That is, if a and p are varied so that their product remains constant, so also does the product aX remain constant where a, p and X are the radius of wire, pressure of air, and critical surface intensity, respectively. Substitution of this relation in the foregoing leads simply to the complete relation given by formula (2).

There is excellent independent experimental evidence in support of all of Townsend's assumptions, with the single exception of that fixing the outer boundary of corona at the surface corresponding to 30 kv/cm., as calculated from the voltage and dimensions of the wire and surrounding cylinder. Photographic

observations by the writer [4] on the diameter of the corona, seem to indicate that the diameter is only approximately that suggested by Townsend. Experiments of this character are, however, difficult, and subject to some uncertainty. A careful study of the potential gradient about a corona-forming wire is greatly needed.

The theory also fails to account for the fact that for the smaller sizes of wire, the surface electric intensity may be raised to values well above 32 kv/cm., without forming corona. This failure is caused by the use of the average electric intensity in the radial thickness of the corona in the first assumption mentioned above. This assumption, therefore, takes no account of the wide difference in the values of the intensity at the surface of the wire and the boundary of the corona.

The sequence of phenomena in the formation of corona would appear then to be somewhat as follows: There are always present in the air a number of free electrons (about 1000 to every cu. cm., or one to each 3.5×10^{16} molecules). Under an electric field, these electrons move and collide with the molecules of the air. If the field is strong enough, the velocity at impact may be sufficient to ionize the neutral molecules and thus form a new electron and a positive ion of about the size of a molecule. If the field is still stronger, the slower positive ions will also begin to form new ions by collision. When this stage is reached, the opposite streams of positive and negative ions generate progressively an increasing number of new ions until the whole gas is saturated, or ionized. This is the phenomenon which is accompanied by the blue glow of an electric discharge, as for example, the corona. Obviously, it starts first at the surface of the corona wire where the electric intensity is greatest. The ions that move outward come to regions of lower intensity and thus lower velocity, and here ions are no longer generated. These moving ions, however, constitute an electric current to the opposite side of the circuit, and it is this current, or leakage, that causes the energy loss in long distance transmission lines when the voltage is raised above that corresponding to the formation of corona. These ions are probably single molecules, or groups of two or three molecules and they move with a velocity of about 1.3 cm. per second per volt per cm. The phenomena, as described, of course take place in extremely short intervals of time, so that observations with continuous and alternating voltages, are in agreement when based on the maximum values of the latter.

THE MEASUREMENT OF HIGH VOLTAGE.

Attention has already been drawn to the extreme constancy of the value of voltage at which corona appears on a clean wire. This fact has often prompted the suggestion that a corona wire be used as an instrument for measuring high voltage. The chief objection has been that for visual observation of the corona, the wire must be viewed in the dark. In addition to this a single wire indicates only one value of voltage, and wires of various diameters must be used in order to extend the range. A corona voltmeter as developed by the writer, which not only avoids the necessity for observation in the dark, but which also is suitable for a wide range of voltage without altering any of the features of the instrument, is described later in this paper. Before describing the corona voltmeter, however, a brief review of other available methods of high voltage measurement is desirable, in order that the improvement offered may be emphasized.

Voltage, or difference of potential, is by definition of the nature of work. Its direct measurement in units of work has probably never been attempted. Difference of potential may be measured in terms of a mechanical force in the so-called absolute electrometer and this is generally spoken of as the absolute measurement of voltage. The method and the instrument are highly elaborate and are rarely used. Practically all present methods of measuring voltage accurately involve comparison with existing standards of voltage, the so-called standard cells. The electromotive force of these cells has in each case been determined, either directly or by comparison, from standards of current and resistance, these standards themselves having their ultimate origin in absolute measurements. The standard cell and the standard resistance are the working standards of to-day, since they are the most convenient, most permanent and most readily reproducible.

Highly developed laboratory methods permit the measurement of continuous voltages of moderate magnitude, say up to 100 or 200 volts, in terms of the standard cell, to a high degree of accuracy. Beyond these values errors arise and the insulation of the apparatus becomes a disturbing factor. Exact measurements of large values of voltage, therefore, are difficult and unusual.

In the case of alternating voltages, the effective values of low voltages may be measured with considerable accuracy. For higher values the transformer offers a simple means of reducing

the voltage to the range in which accurate measurements are possible. The accuracy thus depends on the ratio of transformation of the transformer, and in the so-called "potential transformers" this ratio is itself determined very accurately. Potential transformers become heavy and expensive with increasing voltage and are rarely constructed for voltages above 33,000 volts. Furthermore, this method measures the effective value and not the maximum value of the voltage.

Long distance transmission voltages now reach above 200,000 volts and the requirements for experiment and testing have led to the construction of transformers for 500,000 and even 1,000,000 volts. The question of measurement of these high voltages is an extremely important one. From what has been said, it will be understood that there is no method available for more than an approximate measurement of such voltages. The potential transformer, even if constructed for such values, would be almost as large and expensive as the power transformers themselves and would be under grave suspicion as regards the value of the ratio of transformation. It becomes necessary, therefore, to adopt some rougher, more approximate measure of such high voltages. The convenience and accuracy of direct reading scales are no longer available. The puncture of insulation, the spark discharge, and, as later and now especially described in this paper, the corona on round wires, are utilized as measures of the magnitude of voltage. These methods leave much to be desired in the matters of convenience in manipulation and simplicity, but when the difficulties of controlling and handling high voltages are remembered, it will be seen that it is perhaps fortunate that we have methods of measurement even as convenient and as accurate as these. Obviously, the calibration of such instruments is subject to the uncertainties suggested above, pertaining to the accurate measurement of high voltage. A brief description of a new method of calibration and its application to the corona voltmeter will be given later in this paper.

THE NEEDLE GAP AND THE SPHERE GAP.

The American Institute of Electrical Engineers now authorizes in its Standardization Rules two standards for the determination of high voltage. They are the spark gap between needle points and the spark gap between metal spheres 6.25, 12.5, 25 and

50 cm. in diameter. In each case the voltage is determined by the greatest distance of separation at which a spark will pass. Curves are furnished, showing the relation between voltage and the length of gap for each type of instrument. Correction factors are also given for variations of temperature and pressure from standard conditions.

Neither of the above instruments has given satisfaction nor inspired confidence in usage. The necessity of renewing the needle points after each discharge, the errors introduced by the proximity of surrounding objects, and the variation among successive readings, are the chief objections to the needle gap. In addition, there is the necessity for the accurate measurement of the distance between the needle points which involves a micrometer screw, and the setting of a new zero for each discharge. The specifications state that under the best conditions of experiment, a minimum inaccuracy of 2 per cent. is to be expected.

The sphere gap has been adopted as a standard only recently and comparatively few reports of its performance have been published. The possibilities of the instrument were first noticed by Alexander Russell,[5] who made an effort to establish a definite relation between the dimensions of the sphere gap and its spark-over voltage. DeKowalski and Rappel [6] have taken issue with Russell as to the possibility of accurately expressing the electric intensity between spheres, under different distances of separation, although their experimental observations do not differ widely from those of Russell. Recently Chubb and Fortescue,[7] and Peek,[8] in this country, have published results of tests and calibrations of sphere gaps, and one of the larger manufacturing companies now offers the instrument for sale.

The sphere gap is more constant under repeated readings than the needle gap, although it still shows noticeable variations. While it is free of the necessity for a renewal after each discharge, the surfaces of the spheres deteriorate on a repeated discharge and the instrument is sensitive to dust particles, moisture, or other surface irregularities. It is sensitive to the proximity of surrounding objects and its calibration curve is widely different for the cases, both terminals insulated, and one terminal grounded. The calibrations, as determined by different observers, are not in good agreement and the results of a single observer frequently differ by several per cent. The sphere gap shares with

the needle gap the disadvantage that the reading of the instrument necessitates a spark discharge from the circuit. The occurrence of such a discharge is frequently objectionable, if not dangerous, on account of the oscillations set up in the high tension circuit. This fact makes necessary the use of a high resistance in series with the gap in each case. This adds considerably to the dimensions and complexity of the instrument, as the resistance must be insulated for the voltage to be measured.

THE CORONA VOLTMETER.

A diagram of the essential elements of the Corona Voltmeter is shown on Fig. 1. The corona forms about the central wire, or rod A, when the potential gradient at the surface of A, caused by the application of voltage between A and the case, reaches the value given by formula (2). The voltage corresponding to this gradient by well-known relations, depends only on the diameters of the rod and the inner cylinders B. As now constructed, the cylinder B is always connected to ground.

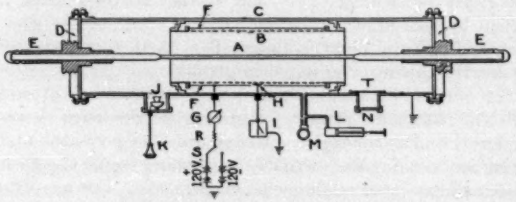
The outer cylinder C, which is also connected to ground, encloses the voltmeter proper, consisting of the wire A and the cylinder B and is air-tight. Means are also provided at L for varying and reading the value of the pressure inside C. Provision is also made at T for reading the temperature. For any observed temperature, it is possible, therefore, to adjust the pressure so that any desired value of δ, the density factor of formula (3), may be obtained. By this means the instrument may be set for a wide range of critical corona-forming intensity and hence of critical corona-forming voltages, with only one wire, or rod. This method of setting the instrument for a definite voltage, by varying the pressure rather than by a change in the size of the rod or other dimension, is one of its novel and characteristic features. In a corona voltmeter of range 40,000 to 100,000 volts, the pressure range is that between 60 cm. and 140 cm. of mercury. This range of pressure is readily accomplished with an ordinary hand pump.

Attention has already been drawn to the disadvantage of the corona as a voltage indicator, imposed by the necessity of viewing it in the dark. It is obvious, therefore, that an instrument which claims superiority over the sphere gap must be free of this objection. The corona voltmeter, as now developed, provides three

methods of detecting the initial appearance of corona, in addition to that of visual observation. These methods involve the use of the gold-leaf electroscope, the galvanometer and the telephone.

The corona is a source of copious ionization and if a few small holes be drilled through the cylinder B, and the electrode H, connected to an electroscope, be placed opposite these holes, the electroscope discharges rapidly as soon as corona appears. The relation between them is very sharply marked and the finest adjustments of voltage for the starting of corona bring about simultaneously the discharge of the electroscope. The writer has described in several papers [9] experiments showing that by this means the start of corona may be read to a maximum inaccuracy of ¼ of 1 per cent.

FIG. 1



Corona voltmeter for 100,000 volts—Central section and connections of auxiliary apparatus.

If the entire surface of the cylinder B be drilled with holes, and an insulated outer cylinder or electrode F completely surround B, a much greater volume of ionized gas may be utilized if this outer cylinder be also connected to ground through a galvanometer and a battery or other source of continuous potential difference. The galvanometer serves as an excellent indicator of the beginning of corona. No current flows until corona forms and then a sensitive galvanometer shows a sharply marked deflection. A portable needle galvanometer of sensitivity 10^{-8} amp. has been used, but a somewhat greater sensitivity than this is desirable.

In the open, the corona emits a low, hissing noise, but when confined by such an outer casing as C of Fig. 1, the sound is gathered and has considerable volume when the ear is placed at an opening in C. There is no sound before corona begins, and the

smallest possible corona gives a sound amply loud for using this method as a detector. As the pressure in C must be varied in order to obtain the range of the instrument, it is not possible to have any openings in it. For this reason, in order to use the sound of the corona as a detector, recourse is had to a telephone transmitter and receiver, as shown in Fig. 1 at J. The arrangement works perfectly and the telephone is perhaps the most convenient and satisfactory of all the methods of detecting the corona. One of its advantages over the galvanometer and electroscope is that it will detect surface irregularities on the corona wire by the characteristic sound of the small sparks which are peculiar to such irregularities.

In normal usage, the usual requirement of a high voltage indicator is that it should be set for a definite voltage, for the purpose of insulation testing, and the like. In the case of the needle gap and sphere gap, this is accomplished by means of the micrometer screw heads, which are set for a certain separation, determined after measuring the temperature and pressure of the atmosphere, and applying the corrections which are given in the tables or curves which accompany the instruments. In the corona voltmeter, no correction factors are necessary. To set the corona voltmeter for a definite voltage, the temperature is read on a thermometer furnished with the instrument and a pressure corresponding to this temperature and the required voltage is read off from a table of values, or a curve. The only adjustment of the instrument which is necessary is to compress or exhaust, by means of a hand-pump, the air in the instrument to this pressure, as indicated by a pressure gauge. The voltage is then raised until corona is formed, as indicated by any one of the methods already described. The voltage may be raised to this value and lowered as many times as desirable, without resetting of pressure or any other adjustment.

For reading an unknown voltage, it is only necessary to set the pressure in the instrument to a value known to correspond to voltages higher in value than that to be measured. The voltage is then applied and then air pressure in the instrument allowed to fall slowly, by leakage through a small valve, to such a value that corona just begins. The value of pressure, together with the temperature in the instrument, will give, by means of the curves or table, the unknown value of voltage. The corresponding opera-

tion in the sphere gap or needle gap involves the repeated opening of the high voltage terminals and the setting of the gap between each pair of readings to shorter and shorter values, until one is reached at which the spark passes. This is a very tedious operation and requires much time.

CORONA VOLTMETERS FOR 50,000 VOLTS AND 100,000 VOLTS.

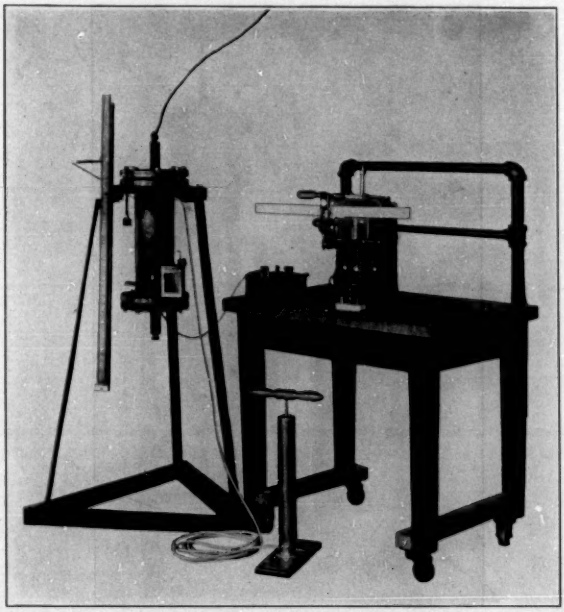
Up to this time the corona voltmeter has been constructed in two sizes, for voltages up to 50,000 and 100,000, respectively. These two instruments are shown in Figs. 2 and 3, which also show the auxiliary equipment for the use of the electroscope, galvanometer and the telephone, as detecting instruments. The pressure and vacuum pump is also shown. In the smaller instrument, the diameter of the inside, or corona, cylinder is 9.51 cm. and its length 25 cm. The corona wire, or rod, is of nickel-plated tool steel .396 cm. in diameter. This instrument is readily portable, weighing about 75 pounds. In the larger instrument, the diameters of rod and cylinder are .635 cm. and 30.7 cm., respectively, and the length of the inner cylinder 92 cm. Both types of instrument have been described in detail in a paper [10] before the American Institute of Electrical Engineers, which also gives the results of a number of tests of their constancy and permanence. The extreme range of air pressure in the outer cylinder necessary for the voltage ranges 20,000 to 50,000 volts, and 40,000 to 100,000 volts is that between 40 and 140 cm. of mercury.

Considering the possible range of voltage for a single corona voltmeter with only one size of corona wire, or rod, it is obvious that a much wider range of pressure than that mentioned above is readily possible. Such a wider range of pressure would, of course, lead to an extension of the voltage range. In the instruments shown in Figs. 2 and 3, the upper limit of voltage has been found in the insulating bushing leading the voltage to the corona-forming wire. Brush discharge takes place over these bushings, as constructed, if the voltage is carried above the upper values which have been given. In both cases, however, these bushings were of experimental construction and there is possibility of considerable improvement. An instrument is now in process of construction which has the general design shown in Fig. 4. In this case only one bushing is used and this has been especially designed for the conditions met in the corona voltmeter.

It is certain that the use of this bushing will permit much higher values of voltage and hence a wider range for the instrument than that already mentioned.

In the new form of instrument, the lower end of the corona rod will be supported by a metal sphere, mounted on top of a post

FIG. 2



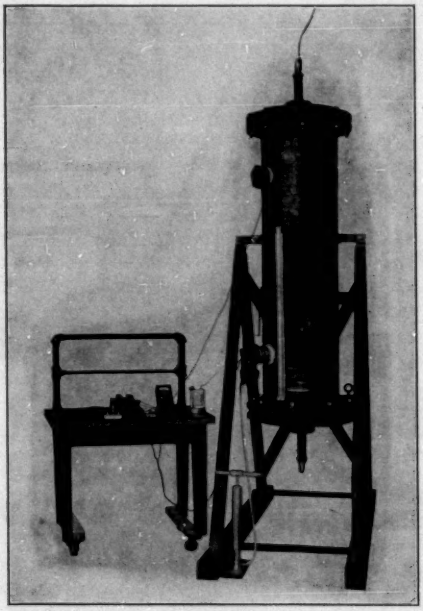
Corona voltmeter for 50,000 volts.

or pedestal type insulator, as indicated in Fig. 4. This insulator is of porcelain, and is of simpler construction and less expensive than a bushing. The metal spheres on the pedestal insulator and also at the lower end of the bushing are for the purpose of avoiding sharp edges and so preventing regions of high electric in-

tensity which might cause corona, or spark-over, before corona forms on the central conductor.

Experiment has shown that a corona wire maintains its surface without deterioration through a very great number of tests; in fact, a moderate corona may be maintained continuously for a

FIG. 3.

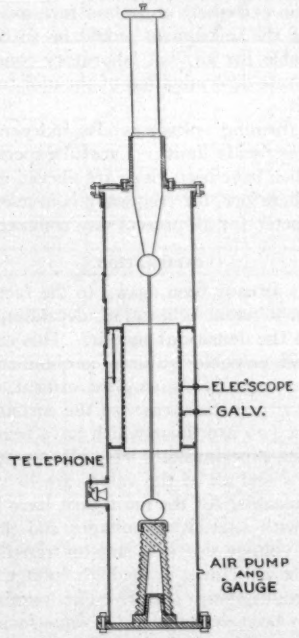


Corona voltmeter for 100,000 volts.

considerable length of time on a nickel-plated corona rod, without impairing its surface to any appreciable extent. In time, however, it does become necessary to remove and clean the corona rod. It may also be desirable to change the rod to one of a different diameter, in order to vary the range. It is important

that these changes may be made as quickly and easily as possible, and for this reason a small opening is provided in the top end-plate of the voltmeter through which a rod may be removed or inserted. This operation is further assisted by the presence of

FIG. 4



Corona voltmeter for 150,000 volts.

two hand holes in the sides of the cylinder, directly opposite the points of support of the corona rod. The several rods of one instrument are similar in all respects, except as to diameter, and they fit readily into a receptacle in the top of the lower sphere and also into a split fitting on the bottom of the upper sphere. These

spheres being rigidly in place thus provide for the accurate centering of the rods.

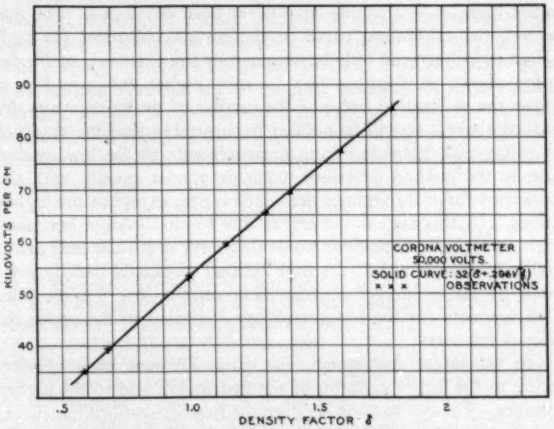
The voltage at which corona forms on a clean round wire is independent of the moisture content of the air, consequently no determination of the moisture content, nor correction for variation in the moisture content, are necessary in the corona voltmeter. This is an extremely important fact, as, if it were not so, the operation of the instrument would be so complicated as to render it unsuitable for any but laboratory conditions, since the control and accurate determination of the moisture content of air are very difficult.

The corona forming voltage is also independent of the frequency within very wide limits. Careful experiment has shown that the laws which have been given are obeyed up to 3000 cycles. No correction, therefore, for frequency is necessary in the use of the corona voltmeter for all present day commercial frequencies.

CALIBRATION.

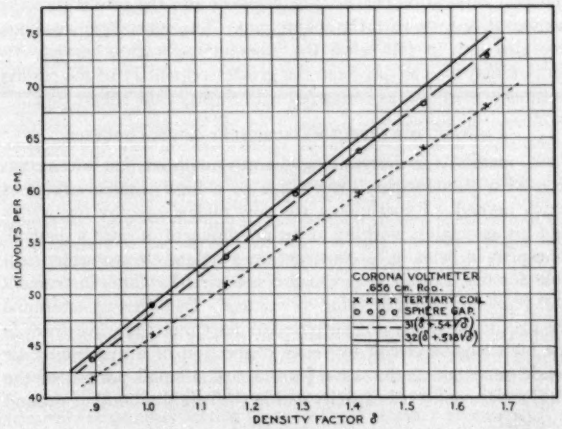
Attention has already been drawn to the fact that the corona voltmeter has an inherent calibration, depending only on its dimensions and on the density of the air. This calibration, which is one of its most valuable features, is obtained from the relation shown by formula (2), giving the critical, or corona forming, electric intensity at the surface of the corona rod. The constants in formula (2) are those which have been determined by the writer. Other experimenters have also made determinations of these constants and all of the values are in very close agreement. These constants, for the most part, have been determined by experiments with alternating voltages and the measurements made on the low voltage side of a step-up transformer, using the ratio of the numbers of turns in the high voltage and low voltage windings as a multiplying factor. The maximum values of voltage have also been determined by wave-form measurements on the low voltage side of the transformers. This method is probably very accurate up to values of voltage in the neighborhood of 30,000 volts. With higher values of voltage, however, the electrostatic capacity of the high voltage transformer winding and of the corona voltmeter, in combination with the leakage reactance of the transformer winding, lead to greater or less error and uncertainty.

FIG. 5



Calibration of corona voltmeter, 50,000 volts.

FIG. 6



Calibration of corona voltmeter, 100,000 volts.

Methods for the accurate determination of voltage directly in the high tension circuit have never been developed. For this reason, the calibration curve of the corona voltmeter for high values of voltage can only be obtained by the extension of the relation shown in formula (2) to such higher ranges. Fig. 5 shows the calibration curve of the smaller of the instruments described above. It will be noticed in this curve that the readings of voltage, as calculated from measurements on the low tension side by the method described, coincide almost exactly with the calculated curve throughout the whole range, except at the higher values. In this region the errors due to the leakage reactance begin to appear. The direction of this error is always such that a higher voltage exists at the high tension terminals than is indicated by the voltmeter measurement on the low tension side. This accounts for the lower readings indicated in the upper region of the curve.

In the larger instrument, the error becomes even greater, owing to the larger capacity of the instrument and to the higher voltages. The comparison between the inherent calibration curve, as calculated from formula (2) and the observed readings is shown in Fig. 6, where the latter fall very markedly below the inherent calibration curve. Fig. 6 shows also the results of some comparative tests with the sphere gap. The sphere gap readings are also seen to fall below the inherent calibration curve. Attention may also be drawn to the greater regularity of the corona voltmeter readings, as compared with those of the sphere gap.

A METHOD FOR DIRECT MEASUREMENT OF HIGH VOLTAGE.

A method for determining directly, without the intermediation of a transformer, the voltage of a high tension circuit, is much needed. Experiments are now under way, by the writer and his associates, working to the development of such a method. The plan in brief is to construct an absolute electrometer, suitable for use directly in a 100,000 volt circuit. This instrument will read the effective value of voltage. In order to determine the maximum value, it is purposed to determine the wave-form in the high tension circuit by series connection of a number of air condensers, taking the wave-form across a small portion of the total series-connected capacity and in the neighborhood of ground potential.

With the development of an accurate method of direct determination of the high voltage, such as mentioned in the foregoing paragraph, it should be possible to determine definitely, and beyond dispute, the constants of formula (2). When this is done, there will be available a new absolute standard of high voltage. Further, it will be possible to construct a standard voltmeter, which may be readily adapted to present commercial needs in the testing of insulation and other cases in which accurate measurement is desirable.

BIBLIOGRAPHY.

[1] J. J. Thomson: Conduction of Electricity Through Gases.
[2] J. S. Townsend: Theory of Ionization by Collision.
[3] J. S. Townsend: *Electrician* 71, June, 1913, p. 348.
[4] J. B. Whitehead: *Trans. A. I. E. E.*, vol. xxi, I, 1912, p. 1093.
[5] Alex. Russell: *Proc. Phys. Soc.*, xxiv, I, 1911.
[6] DeKowalski and Rappel: *Phil. Mag.*, 1909.
[7] Chubb and Fortescue: *Trans. A. I. E. E.*, vol. xxxii, I, 1913, p. 739.
[8] F. W. Peek, Jr.: *Trans. A. I. E. E.*, vol. xxxiii, I, 1914, p. 923.
[9] J. B. Whitehead: *Trans. A. I. E. E.*, vol. xxix, II, 1910, p. 1159.
[10] J. B. Whitehead and M. W. Pullen: *Proc. A. I. E. E.*, vol. xxxv, June, 1916.

The Tungar Rectifier. R. E. RUSSELL. (*General Electric Review*, vol. xx, No. 3, p. 209, March, 1917.)—The name "Tungar" is applied to a hot cathode argon-filled rectifier developed by the research laboratory of the General Electric Company. It has been known for a number of years that a vacuum tube containing a hot and cold electrode acts as a rectifier. Rectifiers utilizing this principle were not practical for many reasons. More recently this principle has been employed in the Kenotron, a rectifier of very high voltages, and also in the Coolidge X-ray tube. These two devices depend for their operation upon the emission of electrons (small particles of negative electricity) from an incandescent filament. In the Kenotron and Coolidge tubes there is the highest possible vacuum, so that the electrons themselves are the only current carriers, and the tubes operate at low current and high voltage. In the Tungar rectifier bulb there is an inert gas at low pressure, which is ionized by the electrons emitted from the incandescent filament. This ionized gas acts as the principal current carrier, with the result that the bulb operates with a very much lower voltage drop (5 to 10 volts) and is capable of passing a current of several ampères, the current limit depending upon the design and size of the bulb. The bulb in general appearance is not unlike a modern gas-filled, coiled-filament incandescent lamp with a third terminal carrying a graphite electrode of relatively large cross-section opposite the customary screw socket to which the terminals of the helical filament are attached.

The bulb rectifies for the reason that on the half cycle, when the incandescent tungsten filament is negative, the electrons from it are being pulled toward the anode by the voltage across the bulb, these electrons colliding with the gas molecules and ionizing them; that is, making them conductive in the direction of anode to cathode. At the same time, on the other half of the cycle, when the filament is positive, any electrons that are emitted are driven back to the filament, so that the gas in the bulb is non-conductive during the half-cycle.

At the present time Tungar rectifiers of the half-wave type are available in three capacities on a 115-volt, 60-cycle circuit: (1) a two-ampère unit for charging three cells at two ampères, six cells at one ampère, and eight cells at 0.75 ampère; (2) a six-ampère 7.5/15-volt unit for charging three or six cells at six ampères; (3) a six-ampère 7.5/75-volt unit for charging three to thirty cells. The bulb life, it is believed, will average 600 to 800 hours. The efficiency compares favorably with other reliable devices of similar capacity, the six-ampère 75-volt rectifier having an efficiency of 75 per cent. when delivering its full output of 450 watts. Work is rapidly progressing on full-wave rectifiers for larger capacities and for telephone or other service where the half-wave cannot be used.

Standard Widths for Wagon Tires. E. C. MCCORMICK. (*U. S. Department of Agriculture, Circular No. 73*, February 12, 1917.) —The Office of Public Roads and Rural Engineering has conducted a series of tests, extending over several years, to determine the traction per ton of total load on tires of various widths suitable for use on country roads of earth and gravel, as well as those of a more improved type. In conducting these experiments the road was prepared by plowing up, grading, and rolling prior to each test, so that the condition of the road at the beginning of each test was as nearly uniform as it was possible to make an earth road. The trips selected for comparison are those in which moisture and atmospheric conditions were practically identical.

With a gross load of 5000 pounds the unit draft decreases with the width of tire up to and including a width of 5 inches. For a 6-inch tire the draft increases, indicating that there is no advantage in increasing the width of tire beyond a certain point. A standard road roller carries a load of 450 pounds per inch of width, and it is not considered advisable to employ this unit of load in any vehicle. For the usual types of wagons employed in farming operations and all general work except the heaviest trucking and certain specialized hauling, the following widths of tires are recommended for various capacities: One-horse wagon, 2000 pounds gross load, 2 inches width of tire; light two-horse wagon, 3500 pounds, 2½ inches; medium two-horse wagon, 4500 pounds, 3 inches; standard two-horse wagon, 6800 pounds, 4 inches; heavy two-horse wagon, 7500 pounds, 5 inches.

THE COLORS OF MOTHER-OF-PEARL.*

BY

A. H. PFUND.

At the request of the U. S. Bureau of Fisheries the following work was undertaken to ascertain the cause of the iridescence of mother-of-pearl. While numerous investigators have studied this problem, their results have been largely of a qualitative nature. Probably the first in the field was Sir David Brewster who, as early as 1853, arrived at conclusions which are in substantial agreement with those held to be correct at the present day. As a result of the present investigation quantitative measurements, substantiating the original conclusions of Brewster, are presented. These results are made possible in consequence of extending the observations into the infra-red region of the spectrum where conditions are much simplified. Incidentally it is shown that much information on this subject may be gained entirely without the use of a microscope.

By following the course of procedure to be outlined it is possible to subject almost the entire surface of an iridescent shell to study. Since, however, the primary purpose of this work is to ascertain the cause of iridescence it was deemed advisable to confine the investigation to clear-cut cases, therefore specimens of shell showing extremely brilliant colors were chosen. Since these specimens formed parts of ornamental pictures and jewelry it is out of the question to ascertain the types of shell from which the specimen were taken.

STRUCTURE OF SHELL.

The structure of the shell of a fresh-water mussel (Abovaria ellipsis (Lea)) is shown in Fig. 1.[2] This is a perpendicular section of the shell (near its growing edge) and shows the disposition of the various layers. Roughly speaking, the shell may be said to consist of three layers:

---

* Communicated by the Author.

[1] "Optics," by Sir David Brewster (1853), pp. 137–149.

[2] Drawing prepared by Dr. R. E. Coker.

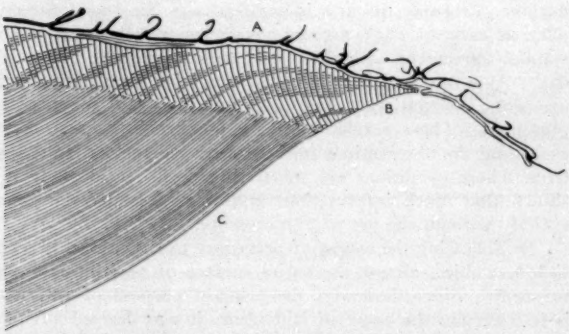
1. An outer horny layer (*a*) (periostracum) which is composed of organic matter (conchiolin).

2. An intermediate layer (*b*) of minute prisms of $CaCO_3$ separated by thin layers of conchiolin. This layer is termed the "prismatic layer."

3. An inner layer (*c*) composed of alternate laminæ of $CaCO_3$ and conchiolin. This is the true mother-of-pearl or "nacre."

That minute layers of conchiolin exist between those of

FIG. 1.



Diagrammatic camera lucida drawing of section of fresh-water mussel shell (Abovaria ellipsis (Lea)).

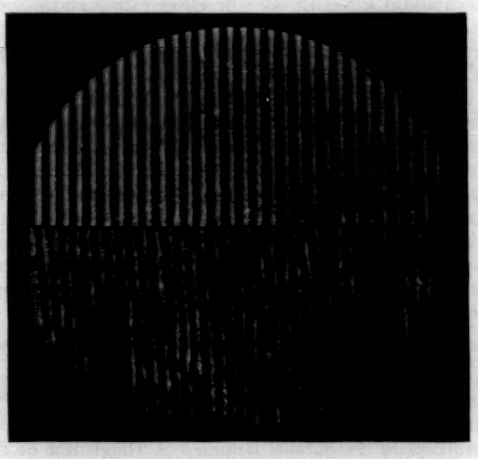
$CaCO_3$ is shown by placing a shell in hydrochloric acid. The calcium carbonate disappears, leaving a flabby, honeycombed mass mass of conchiolin in practically, the form of the original shell.

DIFFRACTION COLORS.

Whereas the minute layers of nacreous matter are continuous on the inside of the shell, they terminate abruptly on the outside. Each layer projects slightly beyond the edge of its predecessor hence the outside of the nacreous portion will show innumerable steps or ridges running parallel to the growing edge of the shell. Such a surface structure is identical with that of a diffraction grating, hence, in case the spacing is sufficiently regular, diffraction colors might be looked for on the outside of a shell.

In order to study these colors it is first necessary to grind off the horny and prismatic layers and polish the nacreous layers by means of a buffing wheel. By permitting the light from an incandescent lamp to be reflected from this surface, pure diffraction colors are observed. As a rule these colors are rather inconspicuous since they are masked by the flood of light coming from the underlying portions. These phenomena may be studied most readily by means of celluloid copies or replicas which are

FIG. 2.
Rowland grating. 7230 lines per inch.



Shell
9000 lines per inch.

made by flowing celluloid dissolved in amyl acetate over the surface of the shell. After the amyl acetate has evaporated the shell is immersed in water for about 20 minutes. The celluloid is then removed and dried on a plate of clear glass.

A microphotograph obtained from such a replica is shown in Fig. 2. For the sake of comparison a similar photograph of a replica taken from a Rowland diffraction grating having 7230 lines per inch, is shown. Since the scale of enlargement is the

same in both cases it appears that the steps or ridges on the outside of the shell are spaced at the rate of about 9000 per inch. This particular shell belonged to a mussel taken from the Mississippi River. As might be expected replicas taken from the inside of the shell revealed no grating structure.

It is obvious that the microscope may be dispensed with entirely in a study of the spacing of these lines for, by measuring the angle of diffraction of light of known wave-length, the grating space may be obtained at once. If a piece of cardboard with a pin-hole 0.5 mm. in diameter be placed in contact with the replica and if a Nernst lamp be viewed through this opening, the two first order diffraction spectra may be seen. If the pin-hole be moved perpendicular to the direction of the lines a study may be made of the striking periodicities in the spacing of the lines. At intervals the lines will be spaced at the rate of 6–8000 lines per inch while the regions in between will show a spacing of 15–20,000 lines per inch. This is not the place to discuss the question as to how these layers are deposited by the living mussel or what the cause of the periodicity giving rise to layers of such remarkable uniformity is. Yet, a study of these questions might be much facilitated by the use of replicas which, when viewed in the white light from a small, intense source, show extremely brilliant colors and color changes over the surface, thus enabling one to tell at a glance where the spacing is coarse or fine.

INTERFERENCE COLORS.

Upon grinding the surface of mother-of-pearl with fine emery all traces of diffraction colors disappear and the brilliant iridescence alone remains. These colors can, obviously, be due only to interference in the parallel laminæ. A rough test of this inference consists in reflecting light almost normally from a patch on the shell appearing red. By increasing the angle of incidence and moving the eye so as to receive always the reflected beam, the color changes in succession to orange, green, and finally blue. The same phenomenon is observed with Lippmann color-photographs and crystals of $KClO_3$ whose structure is known to be laminar. In order to prove even more conclusively the correctness of this explanation, white light of great intensity was reflected from the mother-of-pearl into a spectrometer and, by means of suitable apparatus, the intensity of the radiation in the

near infra-red and visible spectrum was studied with the view of finding indications of interference maxima.

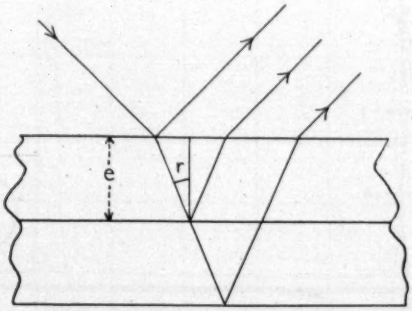
In Fig. 3 the parallel layers of $CaCO_3$ separated by extremely thin films of organic matter are shown. An incident beam of light suffers successive reflections at the various surfaces, each beam lagging behind its predecessor by an amount

$$\Delta = 2\mu e \cos r$$

where μ = refractive index
e = thickness of layer
r = angle of refraction.

Since conditions under which the successive beams are reflected

FIG. 3.

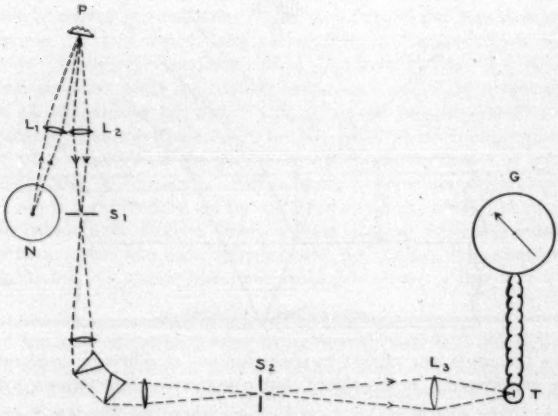


are the same, the phase-change occurring at reflection need not be considered. It is evident that constructive interference will take place whenever $\Delta = \lambda_1, 2\lambda_2, 3\lambda_3$, where $\lambda_2 = \frac{\lambda_1}{2}$, $\lambda_3 = \frac{\lambda_1}{3}$, etc. If, therefore, the reflected light should show maxima at the wave-lengths $\lambda_1, \frac{\lambda_1}{2}, \frac{\lambda_1}{3}$, etc., the conclusion may be drawn that interference between parallel laminæ is the cause of the phenomenon.

The arrangement of apparatus used in this experiment is shown diagrammatically in Fig. 4. An image of the straight coil of incandescent tungsten wire in the gas-filled lamp N was projected on the surface of a polished bit of mother-of-pearl P. This was so adjusted that a beam of brilliantly colored light fell

upon the lens L_2 which focused the light on the primary slit of a monochromatic illuminator I. The monochromatic radiation leaving the secondary slit was focused on the vacuum thermocouple T, connected to a D'Arsonval galvanometer G. Without exception the laminæ in the mother-of-pearl made a small angle with the outer surface, hence the surface reflection was not superimposed on that coming from the laminæ. Since the galvanometer deflections had been shown to be proportional to the intensity of the radiation falling on the thermocouple, such deflections were recorded in the wave-length interval

FIG. 4.

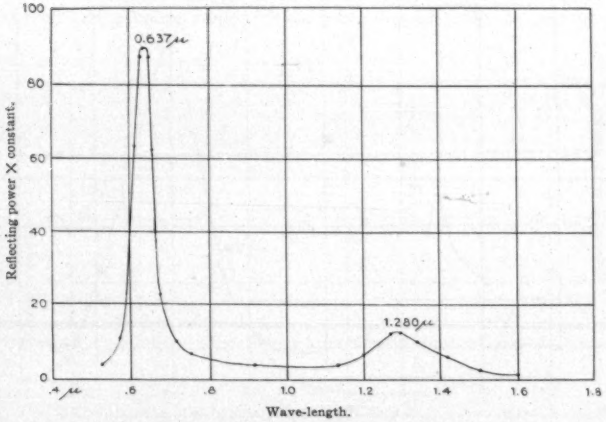


extending from .5μ (visible green) to 2.5μ (infra-red). On account of the lack of planarity of the laminæ no absolute determination of the percentage of energy reflected could be made. Yet by substituting for P a fresh surface of polished silver and by carrying out a similar set of measurements, it was possible to obtain relative values of the reflecting power. A few of the curves obtained are here given. The material used in obtaining the curve shown in Fig. 5 was a polished flake of mother-of-pearl about 0.2 mm. thick. This specimen had a particularly brilliant

spot 1 x 5 mm. in area and from this the light was reflected. The two maxima lie at the wave-lengths 1.28μ and 0.637μ, respectively. Since these wave-lengths are very approximately in the ratio 1 : ½ it is evident that we are dealing with interference maxima of the first and second orders. The sharpness of the maxima indicates a rather remarkable constancy of the thickness of the laminæ.

Practically the same conclusions may be drawn from the curves shown in Figs. 6 and 7. The maxima lie, respectively, at 1.4μ, 0.71μ and 1.86μ, 0.93μ and 0.63μ. As before, the wave-

FIG. 5.



lengths of successive maxima bear the ratios 1 : ½ : ⅓ to a very fair degree of approximation—hence the conclusion may be drawn that the iridescent colors of mother-of-pearl owe their existence to interference of light reflected from the parallel and equidistant laminæ.

It is obvious, without going into details, that these interference phenomena could best be studied in the infra-red spectrum. Not only is the amount of energy great, but the interference maxima are widely separated and hence may be studied readily. A comparison of the curves in Figs. 5, 6 and 7 reveals a marked

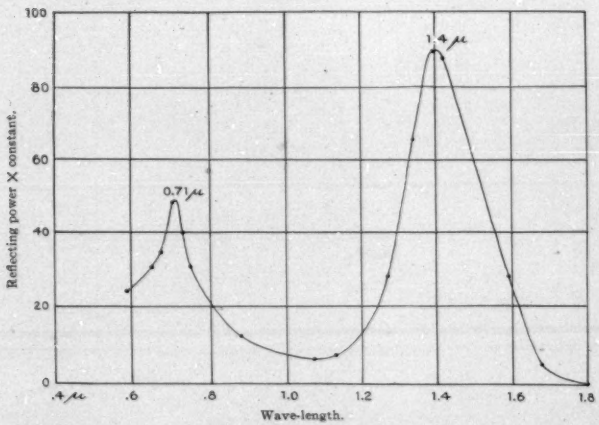
difference in the relative intensities of the maxima for one specimen. While a variety of causes may contribute to this effect, the principal ones are:

(1) A difference in the transparency of the nacreous layer to different spectral regions.

(2) Different dispersion curves of the layer of $CaCO_3$ and conchiolin.

Having investigated highly colored shells it seemed of interest to take up the study of nacreous matter which showed no color but a brilliant "pearly" lustre. A suitable region on the

FIG. 6.



inner surface of a Mississippi River mussel shell was found and from this the reflection curve shown in Fig. 8 was obtained. The lack of sharpness of the maxima indicates that the thickness of the laminæ is far from being constant. It is possible to simulate the appearance of such a specimen by heating a piece of mica in a bunsen flame. In consequence of the heating, the mica is split up into numerous laminæ of widely varying thickness.

An unsuccessful attempt was made to study, in a similar manner, that area on the outside of the shell which exhibits neither color nor pearly lustre. The character of the chalky mate-

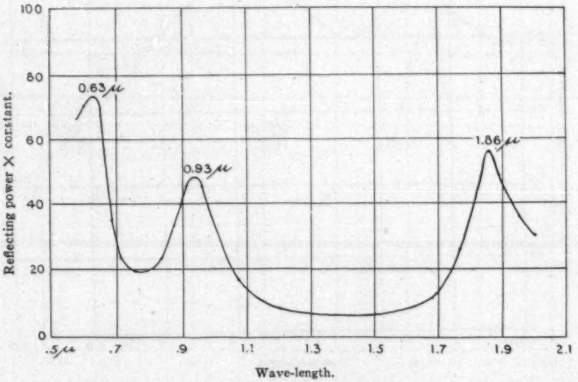
rial in the shell was such as to scatter the light diffusely—thus preventing regular reflection from successive laminæ. That laminæ exist in this region also is certain, for the diffraction colors seen indicate a spacing of the laminæ which is practically the same as that shown by neighboring iridescent portions.

In order to determine the actual thickness (e) of the laminæ it is only necessary to find the refraction index (μ) and substitute in the expression

$$e = \frac{m\lambda}{2\mu \cos r}$$

It is, of course, possible to find a fairly transparent portion of a shell and prepare from this an acute-angled prism by means of

FIG. 7.



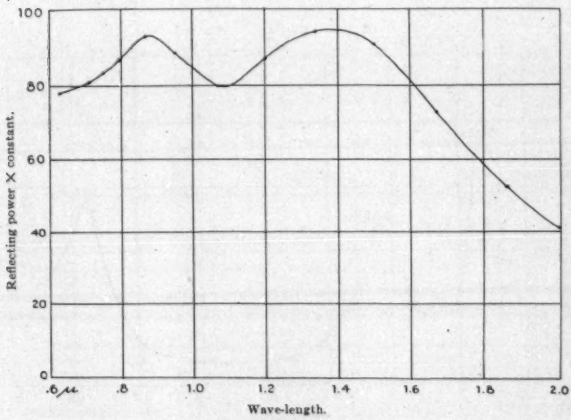
which μ may be determined. However, it frequently happens that the particular specimen studied is not sufficiently transparent. Then, too, such a determination would only be a grand average which might or might not hold for the small element which was used in the study of the interference maxima. It was soon found that the simplest and most satisfactory method of determining μ was to find the wave-lengths λ_1 and λ_2 at which the first order interference maxima lie when the angles of inci-

dence are respectively i_1 and i_2. The calculation of μ follows at once from the easily derivable formula:

$$\mu = \sqrt{\frac{\lambda_2^2 \sin^2 i_1 - \lambda_1^2 \sin^2 i_2}{\lambda_2^2 - \lambda_1^2}}$$

The shift of the position of the interference maxima resulting from a change in the angle of incidence is shown in Fig. 9. The specimen studied was taken from an abalone shell. Corresponding to the angles of incidence $i_1 = 11°$ and $i_2 = 50°$ the wave-lengths of the two first order maxima are 1.478μ and 1.288μ. Upon substituting these values in the foregoing formula,

FIG. 8.



the refractive index (μ) found to be equal to 1.54°.[3] This value of the refractive-index when substituted in expression (i) yields the value for the actual thickness of one lamina:

$$e = 0.48\mu$$

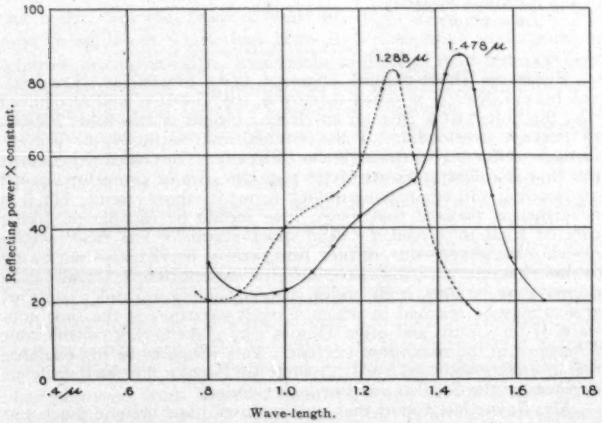
which is the value of the wave-length of greenish-blue light.—

[3] The value of refractive index is practically the mean value for that of the ordinary and extraordinay ray in Iceland-spar ($CaCO_3$) for wave-length 1.45μ. $\mu_o = 1.6361$. $\mu_e = 1.4779$.

Similar determinations of e for other samples of mother-of-pearl all show that the thickness of the lamina is of the order of magnitude 0.4μ to 0.6μ.

Finally, the writer cannot refrain from urging biologists to attack anew the problem of ascertaining the manner in which the layers of nacreous material are deposited. The truly remarkable constancy of thickness of the laminæ demands explanation. That periodic variations in external conditions such as light and darkness, tides, temperature, &c., should be responsible for the deposition of discreet layers seems improbable since the total number of laminæ possessed by a shell of known age is entirely too great to

FIG. 9.



be accounted for on any such hypothesis. Possibly the animal, as such, has nothing to do with the periodicity which gives rise to the laminæ—for, just as the crystals in the minute laminæ exhibited by $KClO_3$ grow only to definite thickness, so may the minute crystals of $CaCO_3$, surrounded by conchiolin, grow only until a certain thickness is reached. These suggestions are merely offered for what they are worth.

SUMMARY.

1. Mother-of-pearl owes its colors to two causes:
   (*a*) Diffraction of light due to a grating-like structure of the terminal edges of successive laminæ.
   (*b*) Interference of light due to reflection from numerous parallel laminæ of sensibly equal thickness.

2. By means of "replicas" the study of diffraction colors was carried out. Interference measurements were obtained in the infra-red region of the spectrum where conditions are much simplified. From these data the thickness of the laminæ for many different samples was found to lie between the limits 0.4μ and 0.6μ.

JOHNS HOPKINS UNIVERSITY,
January, 1917.

Fuses on Short-circuit. ANON. (*The Electrician* (London), vol. lxxviii, No. 19, p. 568, February 9, 1917.)—It is well recognized that the object of a fuse on an electric circuit is two-fold: Firstly, to prevent overloading of the circuit, and, secondly, to prevent damage to the wiring through short-circuits. On ordinary networks the fuse is called upon mainly to play the part of protector against overloading and against the milder forms of short-circuit; but it is nevertheless realized that every fuse should be capable of taking care of what is termed a "dead short-circuit." The fuse takes a certain time to act—this, in fact, being one of its virtues—but, owing to this characteristic, the current that is carried before actual fusion occurs may be very high under certain conditions, and a state of affairs may be reached in which a small variation in the time constant of the circuit and other factors may make a very considerable difference in the maximum current. This seems to be the explanation of effects observed by Mr. Sydney W. Baynes, the chief electrical engineer of the St. Pancras Borough Council.

Mr. Bayne has found that service fuses have become much less satisfactory in recent years—in fact, since the advent of the steam turbine. The currents that may arise on dead short-circuits through 5-ampère or 10-ampère fuse have now become very heavy, this possibly being partly due to the fact that a momentary overload has a less mechanical effect on a steam turbine than on a reciprocating engine, and partly, no doubt, to the much smaller reactance of the turbo-generator. Experiments show that, owing to the heavy currents that may result, there is a tendency for the arc to flash to any earthed metal in the vicinity of the fuse. Consequently fuses of the cartridge type are favored, and for this reason concrete service boxes have been adopted for all service on the St. Pancras network.

THE ORGANIC NITROGEN COMPOUNDS OF SOILS AND FERTILIZERS.*

BY

ELBERT C. LATHROP, Ph.D.

After establishing the fact that the soil was capable of ammonifying acid amides it was decided to ascertain, if possible, if at any time previous to the first sampling period there occurred a decrease in amide nitrogen and at what time the increase in this form of nitrogen was first observable by the analytical methods. For this purpose some of the original mixture of soil and dried blood which had been shown to have undergone no change during storage, was taken and kept at a ten per cent. moisture content. Samples of this soil were taken at short intervals and analysed for their content of ammonia free in the soil and ammonia in the hydrochloric acid extract after hydrolysis. From these data it was possible to arrive at the amounts of amide nitrogen in the soil at the end of each sampling period. The results so obtained, together with the results already obtained upon amide nitrogen, are presented in Table VIII (p. 466).

The results show that during the second and third days there has been a slight increase in amide nitrogen. This must be considered as being due to the formation of protein material by the microörganisms in the form of their protoplasm, and since there has probably been little hydrolysis of the dried blood proteins at this time, the nitrogen necessary for this synthesis may have been derived from the free amino groups of the lysine of the native proteins of the dried blood, or from the free amino groups of lysine or other amino acids in albumoses which are also possibly present in the dried blood. On the fifth day the amide nitrogen has fallen from 60.15 milligrams at the end of the third day to 8.75 milligrams, a loss of about 70 per cent.

* Contribution from the Laboratory of Soil Fertility Investigations, communicated by Dr. Oswald Schreiner and published by permission of the Secretary of Agriculture.

Continued from page 321, March issue.

of this form of nitrogen. Since the number of organisms in the soil are constantly increasing, a portion of the amide nitrogen present in the soil at this time must be present in the form of proteins constituting the protoplasm of these organisms. It would appear, therefore, that practically all of the amide nitrogen of the dried blood proteins has been split off in five days, signifying a deep hydrolysis of these proteins.

TABLE VIII.

Amide Nitrogen in the Soil at Various Periods.

Time in days from the beginning of the experiment.	Milligrams of nitrogen per 100 grams of oven-dried soil.	Amide nitrogen expressed in percentages of hydrolysable nitrogen in original soil.
Original soil	57.14	7.008
2 days	59.77	7.329
3 "	60.15	7.363
5 "	8.75	1.606
6 "	34.31	4.207
7 "	38.42	4.628
8 "	60.42	7.408
13 "	57.48	7.020
18 "	61.39	7.515
20 "	60.72	7.110
44 "	49.13	6.025
86 "	44.38	5.429
148 "	28.27	3.454
240 "	26.38	3.222

The amide nitrogen increases from the 5th to the 6th day from 8.75 to 34.31 milligrams; the 7th day shows a further increase, and on the 8th day the amount of amide nitrogen is about that present in the soil at the end of the 3rd day; from the 8th to the 20th day the amount of amide nitrogen, aside from small fluctuations, remains almost constant. This increase must be considered as being due to the synthetic action of the micro-organisms in the formation of their protoplasmic proteins. In view of the fact that these proteins, in amount, must be much smaller than the proteins of the dried blood, but that the amide nitrogen content of the soil is even greater than the content of the original soil, it would appear that the proteins formed by the microörganisms must be relatively rich in amide linkages.

The amide nitrogen of the soil, during the time covered

from the end of the first period of 18 days to the end of the experiment, 222 days, shows a loss of 57 per cent. This loss is by far smaller than any of the other forms of nitrogen. Since the amide nitrogen was practically all destroyed at the end of the 5th day and then amide nitrogen was synthesized, it would appear that the amide nitrogen built up by the microörganisms exists in proteins which are more resistant to the action of the microörganisms than were the proteins of the dried blood.

The figures in Table VI show that the proportions of amide nitrogen in the soil show an increase up to the 86th day, when 22 per cent. is reached as compared with 7 per cent. in the original soil. The amount then drops off to 19 per cent.

In this connection it is extremely significant that the results obtained by Shorey (1905), Lathrop and Brown (1911), Jodidi (1909, 1911, i, ii), Kelly (1914), Potter and Snyder (1915, i, ii) on hydrolysing the nitrogenous compounds of soils and peats from this country and Hawaii show amounts of amide nitrogen in the soils uniformly higher than are found by acid hydrolysis of animal or vegetable proteins. These figures range between 16 and 30 per cent. of the total hydrolysable nitrogen of the soils. It has further been shown that some of these soils readily ammonify acid amides, indicating that the amide nitrogen exists in protein complexes and not as free acid amides. In the light of the present investigation these various analytical results seem to point to the presence in soils of considerable amounts of microörganismal proteins.

MELANIN AND NON-AMINO NITROGEN.

Owing to the fact that the non-amino nitrogen varies so much throughout the experiment and that the melanins are so little understood, these two forms of nitrogen cannot be profitably discussed.

The results of this investigation are not in strict accord with those recently obtained by Kelly (1915), who studied the decomposition of various sorts of organic matter in Hawaiian soils. He determined the amide, basic, and non-basic nitrogen in casein, dried blood, soy bean cake, cotton-seed meal, linseed meal, cocoanut meal, globulin from cotton seed, and zein from maize, before and after the action of bacteria on these compounds in quartz sand to which a soil infusion had been added previous to incu-

bation. His experiments covered from 3- to 8-day decompositions and the amounts of organic matter used were about one-fourth the amount used in this investigation. He found that, with the exception of linseed meal and zein, the diamino nitrogen was converted into ammonia more rapidly than any other form of nitrogen. In the present investigation the conversion of the diamino nitrogen, arginine, histidine and lysine into ammonia in 240 days amounts to 87 per cent., and the monoamino nitrogen, 89 per cent. The causes for the differences in the results are probably not only the different experimental conditions, but also a difference in the microörganismal flora, producing different types of decomposition.

PROTEINS IN THE SOIL AT THE END OF THE EXPERIMENT.

From the results of the Van Slyke analysis evidence has been found to indicate that there is a formation of protein material taking place in the soil in the course of the decomposition of protein materials, and that perhaps this new protein is somewhat resistant to decomposition. In order to determine whether or not soluble proteins are present in the soil after the decomposition had been proceeding 240 days the portion of the soil which remained was extracted with distilled water for several hours. The solution was then decanted from the soil and filtered. Tests for proteins or protein-like substances in the solution showed that such compounds had not been extracted by distilled water.

The soil was then treated with a 1 per cent. solution of sodium hydroxide for 24 hours and the alkaline solution siphoned off the soil. This solution was acidified with sulfuric acid and was filtered. To this acid filtrate 20 per cent. phosphotungstic acid solution was added until precipitation had ceased, and after allowing the solution to stand for several hours, until the precipitate had settled, the precipitate was filtered off by suction and thoroughly washed with water acidulated with sulfuric acid. The phosphotungstic acid precipitate was suspended in cold distilled water and treated with an excess of barium hydroxide solution in order to free the protein material from the phosphotungstic and sulfuric acids. The excess of barium in the filtrate from the precipitate so formed was removed by carbon dioxide and the barium carbonate was filtered off. The solution was made just acid with dilute sulfuric acid and was boiled for a

minute with a little barium carbonate and then filtered. A light straw-colored, turbid solution was obtained, which behaved in general like solutions of protein material. This solution was tested for the presence of proteins or protein-like substances. It gave precipitates with phosphotungstic, phosphomolybdic, tannic, and picric acids, with mercuric chloride, silver nitrate, and copper acetate. The following tests for proteins were positive: Millon's reaction; Biuret test, reddish violet; Spiegler's ring test, weak; Robert's ring test, weak; Hopkins-Cole reaction; and Liebermann's reaction. Acetic acid and potassium ferrocyanide solution, when added to the soil extract, did not produce a precipitate, but a precipitate was formed when a solution of sodium chloride containing acetic acid was added. The protein material could be salted out by solid sodium chloride, and by ammonium sulfate. A precipitate was formed on the addition of sufficient alcohol to make a 50 per cent. alcoholic solution, and the filtrate from this precipitate when treated with a large amount of absolute alcohol formed a further precipitate. A distinct cloudiness was formed in the solution on the addition of a half saturated solution of ammonium sulfate. By these reactions the presence of proteins or protein-like substances in the soil is established. The exact class to which this protein material belongs could not be determined excepting by a more extended investigation, and this point was not of particular interest. This established the fact that after a 240-day decomposition of dried blood in the soil, proteins, or protein-like complexes, not extractable by distilled water but soluble in dilute alkaline solution, are present in the soil. Whether they are proteins from the bodies of microörganisms in the soil, or whether they are residues from the dried blood which have until this time resisted decomposition by the microörganisms of the soil cannot be stated.

Of interest in this connection is the fact that Walters (1915) has recently reported the isolation from a field soil of protein-like complexes which gave reactions for proteoses and peptones, bodies similar in nature and reaction to the compound here reported.

No attempt was made to isolate free amino acids from the soil after the decomposition period, since the quantities of soil were too small.

EFFECTS OF NITROGENOUS DECOMPOSITION PRODUCTS OF PROTEINS ON THE GROWTH OF THE HIGHER PLANTS.

Proteins and nucleoproteins have long been known to be essential constituents of plant and animal cells. The nitrogenous compounds thus far isolated from soils are for the most part primary protein decomposition products. These compounds may be present in the plant cell in the form of nucleoproteins and other proteins, and in addition it has been shown that these decomposition products of proteins may also occur in the plant tissues as such; for example, xanthine, creatinine, arginine, guanine, etc. These compounds which are so essential to growth must either be synthesized by the plant or they must be acquired in some other manner, such as absorption from the media in which they grow. It becomes of interest, therefore, to observe what effects these decomposition products, known to occur in soils, have upon plants.

There has long been a popular conception that the nitrogen metabolism of plants and animals was fundamentally different. This conception has arisen from the demonstration of two facts; plants are able to build up their protein materials with nitrates and ammonium salts as a source of nitrogen; animals, on the other hand, cannot build up protein from such nutrients as a source of nitrogen but require for their building the already complex organic nitrogen compounds. Recent investigations have demonstrated the unsoundness of this conception, for it has been shown that, although animals cannot utilize the simple nitrogenous compounds, the plant is not confined to these but may also use the more complex nitrogen compounds in their growth.

The building up of protein material by the plant from the nitrate and ammonium salts is a complex chemical transformation which is certainly not completed in one step. While our knowledge of this transformation is experimentally rather uncertain, still, from the fact that many of the simpler compounds which compose the proteins are known regularly to occur in plants, it seems altogether probable that these compounds, the amino acids, purine bases, etc., are first synthesized by the plant and then are linked together to form the still more complex nitrogenous compounds. If, then, the plant is able to absorb these protein decomposition products directly and utilize them in the building up of its proteins, it is obvious that a large expenditure

of energy is saved the plant. In addition, in considering the energy efficiency of metabolism, it becomes apparent that the plant must expend a considerable amount of energy in transforming nitrate nitrogen (NO_3), a highly oxidized nitrogen form, into the amino groups (NH_2) and imino groups (NH), highly reduced forms, in which the nitrogen in amino acids, purine bases, creatinine, etc., is found. If this expenditure of energy is saved the plant by utilizing the building bricks at hand, such as the amino acids, purine bases, etc., in its metabolism, instead of first manufacturing them, it becomes evident that the energy so saved may be used by the plant in other metabolic processes, thus augmenting growth.

The effects of these compounds isolated from soils, together with many other decomposition products of protein material, have been studied, chiefly by Schreiner and his colleagues Reed (1907) and Skinner (1911, 1912), and also by other investigators, notably Hutchinson and Miller (1911). These investigations have shown that many of the compounds are of themselves beneficial to the growth of the plant in water culture solution and that they are apparently absorbed by the plant as such, without first being transformed into ammonia and nitrates. Among the compounds tested are nucleic acid, hypoxanthine, guanine, histidine, arginine, and creatinine. All of these compounds were shown to be decidedly beneficial to the growth of wheat seedlings. Take, for instance, hypoxanthine. The effect of this soil constituent was studied in solutions containing many different ratios of fertilizer elements. The effect of the hypoxanthine was very marked in those cultures containing phosphate and potash, but no nitrate. The average increase in growth in these cultures was 41 per cent., due to the presence of 100 parts per million of hypoxanthine. When nitrate was also present the increase due to hypoxanthine was not so great, but it was shown that in the presence of hypoxanthine less nitrate was consumed by the plants. All other compounds mentioned above behave in the same general way.

In the absence of nitrate, nucleic acid gave an increase of 74 per cent., histidine gave an increase of 30 per cent., arginine an increase of 33 per cent., creatinine an increase of 36 per cent.

In addition to showing that many of these compounds are directly absorbed by the plants, and that they may act as nitrate

sparers, less nitrate being used by the plants in their presence. Schreiner and Skinner (1912) have shown that these compounds collectively are more beneficial than when used singly. For example, they found that taken singly, histidine, creatinine, and asparagine were each beneficial nitrogeneous compounds, causing an increased growth of wheat seedlings, but that when the three compounds were present together in the same solution that the growth was greater than it had been in the presence of any single one of the three. From this they argue that the differences in the action of these compounds are due to an inherent property of the compounds themselves, which make it impossible for one wholly to replace the other in plant metabolism.

It must not be supposed, however, that all nitrogenous compounds are beneficial to plant growth. Guanidine is an especially fine example of this fact. This compound, which has not yet been found in soils, but which, as has been mentioned, may be formed by the action of microörganism on guanine, or arginine, and possibly also creatinine, is decidedly harmful to plant growth. It is toxic to wheat seedlings in the low concentration of 25 parts per million. The action of the compound is manifested on the tops of the plant, causing effects entirely similar to a wilt disease. It is interesting to observe that the presence of nitrates increases remarkably the toxic effects of guanidine, whereas nitrates are usually beneficial.

Several points established by these investigators are of tremendous importance to practical as well as theoretical agriculture. They have shown that not only nitrates and ammonia may serve as the source of nitrogen for the higher plants, but that most of the decomposition products of proteins and nucleoproteins may also be utilized by the plant. These compounds are apparently absorbed unchanged and a combination of them is shown to have a more beneficial action on plant growth than is produced by the compounds singly. They cannot only increase growth in the absence of nitrates, but when nitrates are also present less nitrate is consumed by the plant. Not all nitrogenous decomposition products of proteins are beneficial, some of them being decidedly harmful. Thus not only the nature of the nitrogenous compounds present in the soil is of importance to plant economy, but the diversity of the compounds is equally important. The knowledge thus gained introduces the possibility of interpreting

on rational grounds the action and availability of nitrogenous fertilizers, and other nitrogenous organic matter when introduced into the soil, and shows clearly the necessity of a more intimate chemical knowledge of this sort of material.

EFFECTS OF NITROGENOUS DECOMPOSITION PRODUCTS OF PROTEINS ON THE GROWTH OF MICROÖRGANISMS.

In considering the relation of the nitrogenous constituents found in soils to the problems of soil fertility it is necessary not only to know what the effects of these compounds on the higher plants may be, but the effects which they may have on the growth of the microörganisms in the soil must also be established. It is well known that the general metabolism of the autotrophic and the heterotrophic plants is different and it might be expected *a priori* that the effects of the nitrogen compounds on these two classes of plants would also be different. The microörganisms which grow in the soil seem to be more specialized in their functions than are the higher plants and are more sensitive to the media in which they grow, requiring in many cases rather special conditions. A large number of investigations have been conducted which have more or less bearing on this subject, and it seems that they warrant a brief discussion.

From the standpoint of nitrogen metabolism microörganisms have been divided by Beijerinck (1890, 1901) and Jost (1900) into several fairly distinct classes: (1) *Nitrate organisms,* which seem to thrive as well, if not better, in the presence of nitrates as the sole source of their nitrogen, than if other compounds are also present. (2) *Ammonia organisms,* which seem to prefer ammonia or ammonium salts to other forms of nitrogen as a source of nutrient. (3) *Amide organisms,* which seem to do better in the presence of amides, amino acids, etc., than with either nitrates or ammonia. (4) *Peptone organisms,* which seem to require peptones, the compounds formed among the first products of protein hydrolysis. Amino acids, amides and proteins do not seem to serve as a source of nitrogen for these organisms. (5) *Protein organisms,* which require only proteins as a source of nitrogen. These organisms are known to exist in nature only as parasites. Some organisms can grow on several kinds of media and others are inhibited or cannot grow at all in the presence of one kind or another of nitrogen compounds.

For our knowledge of the various sources of nitrogen which may be used by bacteria we are indebted to the investigations of Bierema (1909), Nawiasky (1908, i, ii), Ellinger (1898, 1899, 1900, 1903), Hoppe-Seyler (1876, 1877, 1878), Baumann (1879, 1880, i, ii, 1883), Sasaki (1912, i, ii), Borchardt (1909), and many other prominent investigators. It is, however, due particularly to Bierema and Nawiasky that we know that bacteria can utilize a wide range of substances for their source of nitrogen. Among the substances which have been tested are aspartic acid, glutamic acid, leucine, phenylalanine, tyrosine, arginine, and many other amino acids, peptones, albumoses, polypeptides, proteins, urea, uric acid, guanidine, creatinine, ammonium salts, both of organic and inorganic acids, acid amides, such as asparagine, etc.

Czapek (1902, i, ii, iii), Emmerling (1902), Butkewitsch (1903), Brenner (1914), Zaleski (1914), and Kossowicz (1912, 1913, i, ii, 1914) have quite thoroughly studied the metabolism of molds. Emmerling showed that molds utilize quite readily the α-amino and λ-amino acids but seem to be unable to utilize the β-amino acids. Czapek studied the growth *Aspergillus niger* on a vast number of nitrogenous compounds, which included amines, diamines, acid amides, nitriles, ureids, purines, nitroderivatives, hydrazines, oximes, cyclic amines, cyanides, and sulfocyanides, amino acids, etc. The mold could not utilize all of these compounds but grew well on a very large number. Kossowicz has shown that molds can utilize urea, uric acid, glycocoll, guanidine, guanine, nitrates, nitrites, and ammonium salts as a source of their nitrogen, and that uric acid, glycocoll and hippuric acid may serve as a source of carbon as well.

Due to the researches particularly of Ehrlich and Neuberg, we have an understanding of the nitrogen metabolism of yeasts. It has been shown, for example, that yeasts may derive the nitrogen for their growth from a single amino acid. They seem to be able to utilize quite well most, if not all, of the amino acids. In so doing they apparently desaminize the amino acid and use in their metabolism only the ammonia formed.

An important class of soil organisms which has not been mentioned is that which utilizes the nitrogen of the air. Reed and Williams (1915) have recently made a study of the effects of certain of the compounds found in soils, together with others

which may occur there, upon the nitrogen fixation of one of these organisms, *Azotobacter*. They report that such compounds as nicotine, picoline, guanidine, and skatol exhibit toxic properties commensurate with those usually ascribed to these substances. Caffeine seems to have a stimulating effect. Many of the nitrogen compounds which are beneficial to plants they found to exercise a marked depression on nitrogen fixation. The simple compounds seemed to be more pronounced in this respect than the more complex. Urea, glycocoll, formamide, and allantoin were especially active in depressing fixation.

In regard to the action of guanidine, a compound toxic to the higher plants, the reports are conflicting. Bierema reports that molds and bacteria ammonify it only very slowly, Shibata reports that *Aspergillus niger* has no effect on it. Czapek and also Kossowicz report that it may be used as a source of nutrient. Reed and Williams report that it is toxic to *Azotobacter*. The reason for this divergence is doubtless due to the difference in the conditions of the media and the organisms studied.

From this brief sketch of the action of these compounds on the growth of the microscopic plants in the soil it becomes apparent that, as is the case with the higher plants, each compound is of significance from the standpoint of plant physiology and plant economy. The appearance in the soil at any time of a compound in sufficient concentration may mean that the normal growth of the higher plants, or the lower plants, or both, will be hindered. The appearance of other compounds may mean that the growth of the plant will be greatly stimulated and hastened. It is probable that all times there exist in the soil, compounds which are beneficial and compounds which are harmful, not only to the higher plants growing on the soil, but also to the organisms which inhabit it. The depression or stimulation of one type of organisms in their growth will, in turn, affect the growth of the higher plants and of other types of organisms.

Thus we see that the whole process is very complex, that it is constantly in a dynamic condition and that the net result of all this will be fertility or infertility, depending on which set of factors predominates in the soil at any one time. Just as it is possible to control the course and direction of a fermentation process, certain end products being obtained, so should it be possible to control these conditions which affect the fertility of

the soil, but it is necessary to know in this case, as in the case of the fermentation process, just what the compounds are which react, and the effects which they have on each other and on the other factors of the soil.

THE CHEMISTRY OF THE NITROGEN OF ORGANIC FERTILIZERS.

Of the three so-called essential elements for plant growth nitrogen is the one which does not occur plentifully in the earth's crust, with few notable exceptions. It must, therefore, be supplied to the soil if fertility is to be maintained. Nitrogen seems to have the quickest and most pronounced effects of the three essential elements and tends to promote the above-ground growth of the plant. It has been stated that one of the possible limiting factors to crop production is the lack of water-soluble nitrogen compounds at critical periods in amounts necessary for the normal development of the crop. The nitrate and ammonium salts are extremely soluble in water and are quickly leached out of the soil. Organic fertilizers, on the other hand, seem to have a more lasting, although not so immediate, effect. Many crops, especially truck crops, are successfully grown when supplied with organic nitrogenous fertilizing materials.

The chemical nature of the nitrogen of the inorganic or mineral fertilizers is quite simple and the changes which they undergo in the soil are considered to be well understood. Unfortunately, the same cannot be said of the organic nitrogenous fertilizers, for we do not know, except in a very general way, much concerning the forms in which the nitrogen exists in these diversified products, and the manner in which they decay in the soil has just begun to be studied from the chemical and biochemical viewpoint.

NATURAL ORGANIC FERTILIZERS.

The organic nitrogenous fertilizers may be divided generally into two classes: Natural organic fertilizers and Processed organic fertilizers. To the first class belong the organic trade wastes and municipal refuse which are of such a character that they may be used for fertilizer purposes without further treatment. To the second class belong the wastes which in order to be used as fertilizers must first undergo some sort of chemical change.

The nitrogen of the fertilizers of the first class exists largely in the form of complex organic compounds, generally in proteins or nucleoproteins which decompose rather easily and quickly in the soil. Dried blood is one of the best representatives of this class of fertilizers. It has been shown in another section of this paper that it is composed of protein materials, and the results of the Van Slyke analysis for the various forms of nitrogen have already been presented. Further, it has been shown that this fertilizer is quickly hydrolysed in the soil and eventually largely ammonified.

Analyses by the Van Slyke method have recently been made of certain other fertilizing materials which belong to this class; for example, cotton-seed meal and tankage. The results of these analyses made by Nollau (1915) and by Grindley and Slater (1915) are presented in Table IX.

TABLE IX.

Analyses of Certain Organic Nitrogenous Fertilizing Materials According to the Van Slyke Method.

	Nollau (1915)		Grindley and Slater (1915)		
Form of nitrogen	Swift's digestor tankage	Cotton seed meal	Cotton seed meal	Tankage	Blood meal
Ammonia nitrogen	10.03	14.06	10.45	6.58	5.85
Melanin nitrogen	6.88	6.27	7.78	4.40	3.95
Cystine nitrogen	2.46	2.74	0.65	1.28	0.69
Arginine nitrogen	12.34	12.77	19.52	14.15	9.16
Histidine nitrogen	2.18	7.57	5.47	4.94	8.53
Lysine nitrogen	2.50	1.94	4.78	7.48	9.73
Monoamino nitrogen	54.73	45.02	42.82	52.39	56.57
Non-amino nitrogen	9.10	7.49	5.34	7.27	4.42

A comparison of these results with those obtained on dried blood shows much similarity in the composition of all of these materials, and it might be expected that their decay in the soil would proceed much as the decay of the dried blood.

THE NITROGEN OF PROCESSED FERTILIZERS.

On the market are a very large number of fertilizers which may be characterized as "processed," *i.e.*, the crude materials, not in themselves permissible as fertilizers, are made to undergo some decided chemical change in order to render them suitable as plant nutrients. It has been found that the availability of the

crude substances is nearly always greatly increased by such processing and that a much larger percentage of the nitrogen in the finished product is soluble in water, although the actual chemical changes produced seem to have received little attention. The chemical compounds in processed fertilizers which are here shown to have direct fertilizer significance have not previously been determined, other than to show that ammonia was formed during the processing and that ammonia is more readily produced from the processed goods.

Since the wastes from which this type of fertilizer is made contain more or less protein, or protein-like substances, it seemed quite obvious that the finished fertilizer must contain more or less of the chemical compounds which would arise from pure proteins by similar treatment in the laboratory. As the action of many of this class of compounds on plants has been determined, it is evident that the finding of such compounds in the fertilizers would throw much light on the question of the availability of the nitrogen in the fertilizer itself.

BASE GOODS A TYPE OF PROCESSED FERTILIZER.

For a chemical study of processed fertilizers a sample of "wet mixed" or "base goods" fertilizer was chosen as a representative of this type of fertilizer material. The base goods was obtained directly from the factory for use in this investigation. This fertilizer is made by the treatment of various trade wastes and refuse, such as hair, tankage, leather scraps, etc., with rock phosphate and the required amount of sulfuric acid. The materials are mixed together in a "den" and the resulting mass is allowed to stand for several days, or until it is cool enough to be conveniently handled. In the course of the reaction the mass reaches a temperature approximating 100° C., and the identities of the original substances are almost or entirely lost Under these conditions it is certain that more or less hydrolysis of the proteins in the crude materials takes place, with the formation of proteoses, peptones, polypeptides or the simple amino acids, the kinds and number of the products necessarily depending on the proportion of the different proteins in the original materials, on the amount and strength of the acid, the length of time of the reaction, and the temperature reached during the treatment.

Hartwell and Pember (1912) have made a study of base

goods in order to determine the availability of the nitrogen contained compared with that of the high grade fertilizers. The product they used was made from hair tankage, garbage tankage, and roasted leather, together with rock phosphate and sulfuric acid. Tables X and XI give their figures for the analysis of the crude materials used in producing the fertilizer and of the finished product.

TABLE X.

Percentages Total Nitrogen in Crude Materials and Finished Product.

(Hartwell and Pember.)

Hair tankage	6.28
Roasted leather	6.49
Garbage tankage	2.87
Base goods including the above	1.68
Water soluble nitrogen in base goods	1.28
Water insoluble nitrogen in base goods	0.40

TABLE XI.

Percentages of Total Nitrogen Present in Different Forms.

(Hartwell and Pember.)

	Before put into den	After removing from den.
In ammonia	6.5	14.3
In water-soluble organic matter	7.8	57.7
In water-insoluble organic matter	85.7	28.0

The experimental work in this investigation was along two separate lines:

(1) Analytical, involving total nitrogen determinations and the separate estimation of the various forms in which the nitrogen may occur.

(2) A determination of the definite chemical compounds present in the fertilizer by suitable methods of isolation and identification.

For the analytical study of the forms of nitrogen in the fertilizer the method of Van Slyke was used in its essential details, excepting that cystine was not determined. The analytical figures obtained by this method appear in Table XIII and will be discussed after the isolation of certain of the constituents has been presented.

The methods used for isolating and identifying the various organic compounds are such as have been used for separating

these compounds from soils and have already been presented.

Since this investigation aims only at an explanation and exposition of the general chemical principles involved in the treatment of trade wastes and other organic material to render the nitrogen contained therein more available for agricultural purposes, it does not aim to present the research methods here employed as general methods for analysing such fertilizers. Nor can the quantitative relationships obtained be expected to apply to all products of similar manufacture, for the reason that the different kinds of nitrogen compounds will necessarily show different proportions according to the nature of the materials which enter into the mixture.

The compounds which were isolated from the base goods are tabulated in Table XII according to the sources from which they have been derived and the chemical groups to which they belong.

TABLE XII.

Organic Nitrogenous Compounds Isolated from Sample of Base Goods.

Arginine, Histidine, Lysine	Diamo acids or hexone bases	Products of protein hydrolysis by acid treatment of raw materials.
Leucine, Tryosine	Monoamino acids	
Guanine	Purine base	Plant constituent or product of hydrolysis of nucleoprotein.
Hypoxanthine	Purine base	Plant constituent, or product of conversion of nucleoprotein base.

THE EXPERIMENTAL RESULTS.

Establishing the presence of these products of acid hydrolysis of proteins, namely, the diamino acids, arginine, histidine, and lysine, and the two monoamino acids, leucine and tyrosine, in the amounts in which they were found is of itself of sufficient evidence to demonstrate that by the acid treatment of the crude materials used in the manufacture of the base goods, the proteins contained therein have been changed. This change is shown to be a deep-seated one, since five of the compounds known to be final products of protein hydrolysis by acids are found. This cannot, however, be taken to mean that the proteins have been

completely hydrolysed by the acid treatment, since it is possible to have present in the products of partial protein hydrolysis, not only the diamino and monoamino acids but also such intermediate compounds as polypeptides, peptones, proteoses, etc.

In this connection the results obtained by use of the Van Slyke method, and given in Table XIII, are of particular interest. For the nitrogen partition two samples of base goods were extracted: (1) with boiling water, and (2) with boiling acid. In the former case only slight further hydrolysis of the materials in the base goods is to be expected, since the free acid in the fertilizer is extremely weak, and the boiling temperature, 100° C., is that reached in the process of manufacture. In the case of the second extract complete, or practically complete, hydrolysis of all of the protein or protein-like materials is to be expected, since in addition to the original hydrolysis the material was boiled with strong hydrochloric acid for 24 hours, a treatment sufficient for the hydrolysis of most proteins. The differences in the results obtained from the analysis of the two extracts may, therefore, be expected to throw some light on the question of the completeness of hydrolysis of the original proteins by the acid processing.

Without discussing the significance of all of these figures obtained by the use of this method it is interesting to note that the differences between the water extract and the hydrochloric acid extract indicate the presence in the base goods of a nitrogenous compound not yet completely hydrolysed.

In order to prove the presence of some intermediate product of protein hydrolysis, which is thus indicated by analytical methods, an aqueous solution of about 2.5 pounds of base goods was made and the diamino acid fraction was precipitated with phosphotungstic acid in the presence of 5 per cent. sulfuric acid. The precipitate which formed was allowed to stand over night and after filtering it was washed thoroughly with 5 per cent. sulfuric acid and dissolved in sodium hydroxide. The phosphotungstic acid was then precipitated by adding barium hydroxide solution, and after filtering, the excess of barium was removed by adding sulfuric acid until a neutral reaction was obtained. Portions of this solution were tested for peptones, proteoses, etc., with the following results: (1) The biuret test was positive; (2) a precipitate was obtained on saturation of the solution with

ammonium sulfate, or with sodium chloride; (3) when the filtrate from the latter solution was treated with acetic acid a cloudy precipitate developed; (4) precipitates were also obtained with sulfuric acid, hydrochloric acid, phosphomolybdic acid and with phosphotungstic acid; (5) a precipitate was formed on the addition of alcohol to the solution. This precipitate was filtered off, dissolved in dilute alkali, and on addition of a very dilute copper sulfate solution the biuret reaction was again obtained. These reactions are those which are given by proteoses and by the proteins and confirm the conclusions arrived at from the results with the Van Slyke method. The Millon reaction and the Hopkins-Cole reaction were both negative, showing the absence from this protein-like material of the tyrosine and tryptophane radicals.

TABLE XIII.

Nitrogen Forms as Determined by the Van Slyke Method.

Form of nitrogen	Results expressed in per cent. of Base goods		Total N in base goods	
	Extract		Extract	
	H_2O	HCl	H_2O	HCl
Total nitrogen	1.610	1.610	....	....
Total soluble N	1.372	1.435	85.24	88.64
Total insoluble N	0.238	0.175	14.76	11.36
Amide N	0.374	0.382	23.23	23.70
Melanin N	0.031	0.074	1.95	4.61
Arginine N	0.111	0.104	6.89	6.46
Histidine N	0.117	0.070	7.26	4.38
Lysine N	0.081	0.117	5.06	7.26
Monoamino acid N	0.543	0.546	33.75	33.92
Non-amino N	0.114	0.133	7.10	8.27

A very large number of compounds intermediate between the protein and its primary hydrolysis products may occur, depending on a great variety of conditions, so that the actual identification of the compounds under discussion would be a difficult matter. However, the nature of this compound may be approximately determined by the results obtained in the study of the two extracts by the Van Slyke method. These results indicate the presence in the base goods of a compound of a proteose nature, which, since it gives a biuret test, must be composed of at least three amino acids. The results indicate still further that the compound is composed of acid amide radicals, diamino acids—particularly lysine—and monoamino acids, those containing amino nitrogen, and especially those containing non-amino nitro-

gen. Since the figures obtained by the nitrogen partition method are subject to a certain amount of error when applied to such a mixture, the figures can be taken as only approximate for the various forms of nitrogen which make up this compound.

In Table XIV are given the primary hydrolysis products of a number of proteins which may be present in the base goods. These results were obtained by the esterification method and show how the different proteins vary in the nature and amounts of the units composing them. Many monoamino acids, besides leucine and tyrosine, occur in these proteins, and there must consequently be present in the base goods amino acids other than the two isolated. This is apparent from the composition of the various proteins shown in the table. Owing to the large amounts of amide nitrogen in the fertilizer, which was split off by the acidulation of the original proteins of the trade wastes, it may be concluded that considerable quantities of aspartic and glutamic acids are present in this sample of base goods.

TABLE XIV.

Products of Acid Hydrolysis of Various Proteins.

Compound	"Synotin" from cattle (1)	Keratin from sheep's horn (2)	Keratin from sheep's wool (2)	Keratin from horse's hair (3)	Halibut muscle (4)	Ox muscle (5)	Legumin from peas (6)
Glycocoll (a)	0.5	0.5	0.6	4.7	0.0	2.1	0.4
Alanine (a)	4.0	1.6	4.4	1.5	(?)	3.7	2.1
Valine	0.9	4.5	2.8	0.9	0.8	0.8	...
Leucine (a)	7.8	15.3	11.5	7.1	10.4	11.7	8.0
Phenylalanine (a)	2.5	1.9	....	0.0	3.1	3.2	3.8
Tyrosine (a)	2.2	3.6	2.9	3.2	2.4	2.2	1.6
Serine	...	1.1	0.1	0.6	(?)	(?)	0.5
Cystine (a)	...	7.5	7.3	8.0	...	...	...
Proline	3.3	3.7	4.4	3.4	3.2	5.8	3.2
Aspartic acid (a)	0.5	2.5	2.3	0.3	2.8	4.5	5.3
Glutamic acid (a)	13.6	17.2	12.9	3.7	10.1	15.5	17.0
Tryptophane	...	...	...	...	+	+	+
Arginine (a)	5.1	2.7	...	4.5	6.4	7.5	11.7
Histidine (a)	2.7	...	...	0.6	2.6	1.8	1.7
Lysine (a)	3.3	0.2	...	1.1	7.5	7.6	5.0
Ammonia (a)	0.9	...	...	...	1.4	1.1	2.1

(1) Abderhalden and Sasaki (1907)
(2) Abderhalden and Voitinovici (1907)
(3) Abderhalden and Wells (1905); Agiris (1905)
(4) Osborne and Heyl (1908)
(5) Osborne and Jones (1909)
(6) Osborne and Heyl (1908)
(a) Physiological action on plant growth has been determined.

The conclusion to be drawn from the results obtained by the examination of this fertilizer by means of the analytical and isolation methods is as follows: The process by which the nitrogen of certain trade wastes, such as hair, leather, garbage, etc., is made more available is recognized as a process of partial hydrolysis of the complex proteins contained in such materials, resulting in ammonia, amino acids, etc., all of which are more readily available than the original protein materials; this hydrolysis is almost complete, the nitrogenous compounds formed being principally the primary products of protein hydrolysis, together with a small amount of proteose-like compound which has not been fully decomposed.

THE AVAILABILITY OF THE NITROGEN OF ORGANIC FERTILIZERS.

The question of the agricultural value of organic fertilizers is one of vital importance to the farmer and to the producer as well. The exploitation of agricultural fertilizers of little or no agricultural value and their use in mixed fertilizers has been a contributing factor for the necessity for state laws and rigid chemical inspection by the state regarding the labeling and sale of such goods. And not until the chemical nature of these products and their biochemical changes in the soil in relation to their effects on plant growth are thoroughly understood will this matter be placed upon a strictly equitable basis.

The determination of the agricultural value or availability of organic nitrogen fertilizers is a knotty problem and one which has received extended study. Numerous methods have been proposed for the determination of this factor, and while many of them give helpful results and have received trade recognition, all of the strictly chemical methods are open to objection. This is due to the fact that the chemical nature of the nitrogenous substances under examination is not known or only guessed, account being taken only of the ammonia formed by the chemical treatment involved and the consideration of the intermediate products of decomposition being neglected. The methods are consequently empirical and the application of empirical methods to the analysis of unknown heterogeneous substances is not apt to lead to a real solution.

The nature of the decomposition products of organic fertilizers in the soil is but partly understood. Ammonification and

nitrification have received much attention, but the intermediate decomposition products have not been investigated to such an extent, and the action of these in affecting plant growth has but recently been receiving proper attention. It has been shown that a large number of nitrogen compounds, especially the decomposition products of proteins or nucleoproteins, are physiological factors in plant growth, and their appearance either in the fertilizer or their appearance in the soil as decomposition products of the fertilizer therefore becomes of economic importance.

Of the fertilizers which are composed most largely of protein material, such as dried blood, cotton seed meal, fish scrap, and feathers, some are classed as being high-grade and some as low-grade. The distinction between these different grades of protein materials is that some of them decay very rapidly in the soil, while others decay only very slowly or not at all. In other words, from the biochemical viewpoint the more available ones are easily hydrolysable and the less available are hydrolysed only with extreme difficulty. In order to be used by the plant the nitrogenous material must be in a soluble form and apparently in a form simpler in structure than the protein itself.

In considering the availability of the nitrogen of organic fertilizers it is evident from the discussion which has preceded that a determination of the amount of nitrogen in the form of nitrate or ammonium salts in the fertilizer will not give an adequate idea of its agricultural value. It is equally obvious that a simple determination of the amount of ammonia formed by means of various chemical treatments will not solve this question, since such a determination will not indicate the amount of the intermediate compounds formed by the decay of the organic matter of the fertilizer in the soil, nor will it show their character or their action on plant growth. It is certain that a very large number of nitrogenous compounds in the soil besides nitrates and ammonium salts are of direct importance to plant growth. The question of the availability of nitrogen compounds can therefore only be answered when the nitrogen compounds contained in the fertilizer can be determined in amount and at the same time classified according to their physiological action on plant growth. It is hardly necessary to state that such a method does not exist at the present time and that the physiological action of only a part of the nitrogenous compounds present in the fertilizer is known.

However, from the results obtained from the chemical study of base goods, which has just been reported, it is possible to draw certain conclusions as to the availability of this fertilizer. Both of the purine bases isolated from base goods are beneficial to plant growth, causing nitrogen increases in the plant; and hypoxanthine and the first two diamino acids act as nitrate sparers. Leucine is also beneficial to plant growth, but the action of tyrosine, in the light of later investigations, is somewhat doubtful. Of the other monoamino acids which may be present in the fertilizer, aspartic acid, glutamic acid and glycocoll have been found to be beneficial. The action of alanine is somewhat doubtful, it apparently being beneficial in low concentrations, while phenylalanine is reported as harmful. The action of cystine on the growth of plants is somewhat doubtful, owing to its insolubility in water. Thus, six of the seven compounds isolated from the base goods are actually available to plants as such and have a beneficial action. Of the monoamino acids, other than the two isolated from base goods, which have been studied in regard to their action on plant growth, three have been found to be beneficial, two doubtful and one is reported as being harmful.

The high-grade nitrogenous fertilizers, such as dried blood, are considered to have a high degree of availability, owing to the fact that the nitrogenous materials when placed in the soil quickly undergo the process of ammonification and nitrification, the nitrogen thus being changed into a form which can be immediately used by the plant. In fact, Lipman (1912) has proposed a method for the determination of the availability of the nitrogen of organic fertilizers, depending on the amount of ammonia produced under biological conditions in a given length of time. It is evident from the investigations here presented that such a method does not tell the whole story, since in the decomposition of protein materials, such as dried blood, intermediate compounds are formed which are undoubtedly of themselves beneficial to plant growth. In order, therefore, to understand the complete action of such nitrogenous fertilizers as base goods, it is necessary to know how the compounds contained in them are acted on by the ammonifying organisms. Jodidi (1912) has shown that amino acids and acid amides are quite readily ammonified when placed in an agricultural soil, the rate of ammonia formation and the amount of ammonia formed depending

apparently upon the chemical structure of the particular compound under consideration. In general, he found that the simpler the chemical structure of the nitrogen compound, the more quickly and readily it was ammonified. In the light of these facts, it appears that polypeptides, peptones, proteoses, and proteins would be ammonified still more slowly than amino acids, since their structure is increasingly more complex.

Hartwell and Pember (1912), in their study on the availability of the nitrogen of base goods, by means of plant tests, found that it had apparently as high an availability as dried blood, the water soluble nitrogen having even higher availability. From the nature and amounts of the nitrogenous compounds in base goods this might be predicted. In the case of the dried blood, the nitrogen is practically all in the form of complex protein materials which must be broken down into the simpler compounds by the action of the soil organisms, with the formation of ammonia and other nitrogenous compounds, some or all of which may be of physiological importance to plants. With the base goods the case is a little different; the greater part of the nitrogen is at once available for plant use, and at the same time these available compounds may be changed more quickly and easily by the soil organisms into ammonia and nitrate, which in turn are used by the plant. The soluble nitrogen of the base goods should therefore be in a more readily available form than the nitrogen of dried blood or other nitrogenous fertilizers which are entirely of a protein character.

THE CHEMICAL PRINCIPLES UNDERLYING THE UTILIZATION OF NITROGENOUS TRADE WASTES.

It has already been stated that in order that the plant may make use of the nitrogen of even high-grade organic fertilizers, it is necessary for the proteins therein to be at least partially decomposable by the biological and biochemical agencies of the soil. The low-grade organic nitrogenous fertilizers resist decomposition by these biological and biochemical agencies, and their nitrogen is, therefore, considered to be less available for plant use. The guiding idea behind the processes proposed for the treatment of trade wastes, which will not decompose easily in the soil as such, is to change the nitrogen compounds contained in them in such a way that ammonia is formed and that their decay in the soil is more rapid.

Much of the nitrogenous material in trade wastes is of a protein nature, since the products from which these wastes are derived are of either animal or vegetable origin. Such, for example, is the case with the wastes used in the manufacture of base goods. It has been shown that by the process used in the case of this fertilizer the non-available nitrogenous materials have been made highly available, not only because the nitrogen compounds can be ammonified quickly in the soil, but also because these compounds are directly utilizable by plants. This change in the nature of the nitrogen compounds has been brought about by the partial hydrolysis of the proteins contained in the various trade wastes used in the manufacture of the fertilizer. When proteins decompose through natural conditions, be they in the soil or out of it, a certain amount of hydrolysis of the proteins takes place, and if the decomposition is allowed to proceed long enough under proper conditions complete hydrolysis will result.

The principle involved in making the nitrogenous material in the soil available and in increasing the availability of low-grade nitrogenous material by factory treatment is therefore the same. In other words, the general chemical principle to be applied in making available the nitrogen of low-grade fertilizers, trade wastes, etc., is that of partial or complete hydrolysis by any suitable means of the proteins contained in the wastes. Partial hydrolysis of proteins may be accomplished by means of heat, boiling, steaming, heating under pressure; both partial and complete hydrolysis may be obtained by treating with strong acids or alkalies, either in the cold for a long time or heating to a high temperature, the extent of the hydrolysis depending on the several conditions. An examination of the patent literature shows that all of these means have been proposed for the treatment of trade wastes and other organic materials, although the actual chemical principle of hydrolysis involved in the treatment is not considered. Also, in a number of processes in actual use various of these treatments are practised, resulting in different degrees of hydrolysis of the original proteins. While the availability of the nitrogen of a fertilizer depends on the substances in which the nitrogen is contained, it also depends on the extent of the hydrolysis of the proteins used in the manufacture. It may be stated that in general the more extended and final the hydrolysis, the more available the nitrogen of the compounds formed, since,

as has been shown, the final products of hydrolysis are utilized by the plants as such and are at the same time more readily changed into ammonia by soil organisms than are the intermediate compounds produced by partial hydrolysis.

BUREAU OF PLANT INDUSTRY,
WASHINGTON, D. C.

LITERATURE CITED.

Abderhalden, E., 1898: Zur quantitative vergleichenden Analyse des Blutes. *Zeit. physiol. Chem.* **25**, 65–115.

Abderhalden, E., and Sasaki, T., 1907: Die Monoaminosäuren des "Synotins" aus Rindfleisch. *Zeit. physiol. Chem.* **51**, 404–408.

Abderhalden, E., and Voitinovici, A., 1907: Hydrolyse des Keratins aus Horn und aus Wolle. *Zeit. physiol. Chem.* **52**, 348–367.

Abderhalden, E., and Wells, H. G., 1905: Die Monoaminosäuren des Keratins aus Pferdhaaren. *Zeit. physiol. Chem.* **46**, 31–39.

Ackermann, D., 1910, i: Ueber den bakteriellen Abbau des Histidins. *Zeit. physiol. Chem.* **65**, 504–510.

Ackermann, D., and Kutscher, Fr., 1910, ii: Ueber die Aporrhegmen. *Zeit. physiol. Chem.* **69**, 265–281.

Ackermann, D., and Schütze, H., 1911. Ueber Art und Herkunft der flüchtigen Basen von Kulturen des Bakterium Prodigiosum. *Arch. Hyg.* **73**, 145–152.

Amberg, S., and Jones, W., 1911: Ueber die bei der Spaltung der Nucleine in Betracht Kommenden Fermente mit besonderer Berücksichtigung der Bildung von Hypoxanthin in der Abwesenheit von Adenase. *Zeit. physiol. Chem.* **73**, 407–415.

Argiris, A., 1905: Zur Kenntniss des Neurokeratins. *Zeit. physiol. Chem.* **54**, 86–94.

Baumann, A., 1887: Ueber die Bestimmung des im Boden enthaltenen Ammoniak-Stickstoffs und über die Menge des assimilarbaren Stickstoffs im unbearbeiteten Boden. *Land. Vers. Stat.* **33**, 247–303.

Baumann, E., 1879: Ueber die Bildung von Hydroparacumarsäure aus Tyrosin. *Ber.* **12**, ii, 1450–1454. 1880, i: Zur Kenntniss der aromatischen Produkte des Thierkörpers. *Ber.* **13**, 279–285. 1880, ii: Weitere Beiträge zur Kenntniss der aromatischen Substanzen des Thierkörpers. *Zeit. physiol. Chem.* **4**, 304–322. 1883: Zur Kenntniss der aromatischen Substanzen des Thierkörpers. *Zeit. physiol. Chem.* **7**, 282–291.

Beijerinck, M. W., 1890: Culturversuche mit Zoochlorellen, Lichenengonidien und anderen niederen Algen. *Bot. Ztg.* **48**, 725. 1901. Sur les ferments lactiques de l'industrie. *Arch. neerland* ii, **6**, 212–243.

Bertholet, M., and André, G., 1886: Sur les principes azotes de la terre. *Compt. rend.* **103**, 1101–1104. 1891: Sur l'odeur propre de la terre. *Compt. rend.* **112**, 598–599.

Bierema, S., 1909: Die Assimilation von Ammon-, Nitrat- und Amidostickstoff durch Mikroorganismen. *Centralb. Bakt. Parasitenk.* **23**, ii. Abt. 672–726.

Bolley, H. L., 1912: Interpretations of results noted in experiments upon cereal cropping methods after soil sterilization. *Science* **33**, 229–232.

Boehmer, C., 1883: Untersuchungen einiger Gemüsarten auf ihren Gehalt an Eiweisstoffen und nicht eiweissartigen Stickstoff-Verbindungen. *Landw. Vers. Stat.* **28**, 247–262.

Bopp, F., 1849: Einiges über Albumin, Casein und Fibrin. *Liebig's Ann.* **69**, 35.

Borchardt, L., 1909: Fäulnisversuche mit Glutamin- und Asparaginsäure. *Zeit. physiol. Chem.* **59**, 96–100.

Boullay, P., 1830: Dissertation sur l'Ulmine (acide ulmique) et sur l'Acide azulmique. *Ann. chim. phys.* **43**, 273–285.

Braconnot, H., 1819: Sur la Conversion du corps ligneux en gomme, en sucre, et en un acide d'une nature particuliere, par le moyen de l'acide sulfurique; conversion de la meme substance ligneuse en ulmine par la potasse. *Ann. chim. phys.* **12**, 172–195.

Brenner, W., 1914: Die Stickstoffnahrung der Schimmelpilze. *Centrlb. Bakt. Parasitenk.* **40**, ii, Abt., 555–640.

Burian, R., 1905: Ueber die oxydative und die vermeinthliche synthetischen Bildung von Harnsäure in Rinderleberauszug. *Zeit. physiol. Chem.* **43**, 497–531.

Butkewitsch, W., 1903: Umwandlung der Eiweisstoffe durch die niederen Pilze im Zusammenhange mit einigen Bedingungen ihrer Entwickelung. *Jahrb. f. wissenschaftliche Bot.* **38**, 147–229.

Capranica, S., 1880: Vorläufige Mittheilung einiger neuer Guanin-Reactionen. *Zeit. physiol. Chem.* **4**, 233–236.

Chardet, G., 1914: Le chimisme des sols, l'evolution des acides amines. *Rev. gen. chim.* **17**, 137–144.

Czapek, F., 1902, i: Untersuchungen über die Stickstoffgewinnung und Eiweissbildung der Pflanzen. *Beiträge Chem. Physiol. Pathol.* **1**, 538–560. 1902, ii: Untersuchungen über die Stickstoffgewinnung und Eiweissbildung der Schimmelpilze. *Beiträge Chem. Physiol. Pathol.* **2**, 557–590. 1902, iii: Untersuchungen über die Stickstoffgewinnung und Eiweissbildung der Schimmelpilze. *Beiträge Chem. Physiol. Pathol.* **3**, 47–66.

Czermak, W., 1912: Ein Beitrag zur Erkenntnis der Veränderungen der sog. Physikalischen Bodeneigenschaften durch Frost, Hitze und die Beigabe einiger Salze. *Landw. Vers. Stat.* **76**, 74–116.

Darbishire, F. V., and Russell, E. J., 1907: Oxidation in soils, and its relation to productiveness, ii: The influence of partial sterilization. *J. Agr. Sci.* **2**, 305.

Deherain, P. P., and Demoussey, M. E., 1896: Sur l'oxydation de la matiere organique du sol. *Ann. agron.* **22**, 305–337.

Detmer, W., 1871: Die natürlichen Humuskörper des Bodens und ihre landwirtschaftliche Bedeutung. *Landw. Vers. Stat.* **14**, 248–300.

Dietrich, 1901–02: Versuche über den Einfluss der Bodensterilisation auf das Wachsthum der in dem sterilisirten Boden cultivirten Pflanzen. *Jahresber. Landw. Vers. Marburg.*, p. 16–17.

Dojarenko, A. G., 1901–02: Der Stickstoff des Humus. *Landw. Vers. Stat.* **56**, 311–320.

Dox, A. W., 1910: The intracellular enzymes of Penicillum and Aspergillus. *Bul.* **120**, *Bureau of Animal Industry*, U. S. Dept. Agr.

Dundonald, The Earl of, 1795: A Treatise Showing the Intimate Connection that Subsists between Agriculture and Chemistry. (Book) London, 1795.

Eggertz, C. G., 1889: Studien und Untersuchungen über die Humuskörper der Acker-und Moorerde. *Centralb. i. agr. Chem.* **18**, 75–80.

Ehrlich, F., 1905: Ueber die Entstehung des Fuselöles. *Zeit. Verein Rübenzucker-Ind.* 539–567. 1906, i: Die chemischen Vorgänge bei der Hefegärung. *Biochem. Ztschr.* **2**, 52–80. 1906, ii: Zur Frage der Fuselölbildung der Hefe. *Ber.* **39**, 4072–4075. 1907, i: Ueber die Bedingungen der Fuselölbildung und über ihren Zusammenhang mit dem Eiweissaufbau der Hefe. *Ber.* **40**, 1027–1047. 1907, ii: Die Rolle des Eiweiss und der Eiweissabbauprodukte bei der Gärung. *Jahresber. d. Versuchs. u. Lehranstalt f. Brauerei in Berlin*, **10**, 515–529. 1911: Ueber die Bildung des Plasmaeiweisses bei Hefen und Schimmelpilzen. *Biochem. Ztschr.* **36**, 477–497.

Ehrlich, F., and Pistschimuka, P., 1912: Ueberführung von Aminen in Alkohole durch Hefe und Schimmelpilze. *Ber.* **45**, 1006–1012.

Einhof, H, 1805: Neues allgemeines, *Jour. Chem.* **6**, 381. *Gmelin's Handb. of Chem. trans., by Watt.* 1866, p. 459.

Ellinger, A., 1898: Bildung von Putrescin (Tetramethylendiamin) aus Ornithin. *Ber.* **31**, iii, 3183–3186. 1899: Zur Constitution des Lysins. *Ber.* **32**, iii, 3542–3546. 1900: Die Constitution des Ornithins und des Lysins. Zugleich ein Beitrag zur Chemie der Eiweissfäulniss. *Zeit. physiol. Chem.* **29**, 334–348.

Ellinger, A., and Gentzen, M., 1903: Tryptophan eine Vorstufe des Indols bei der Eiweissfäulniss. *Beiträge Chem. Physiol. Pathol.* **4**, 171–174.

Emmerling, O., 1897: Die Zersetzung von Fibrin durch Streptococcen. *Ber.* **30**, 1863–1868. 1902: Aminosäuren als Nährstoff fur niedere Pflanzen. *Ber.* **35**, ii, 2289–2290.

Erlenmeyer, E., and Lipp, A., 1883: Synthese des Tyrosins. *Liebig's Ann.* **219**, 161–178.

Fischer, Emil, 1882: Ueber Caffein, Theobromin, Xanthine und Guanin. *Liebig's Ann.* **215**, 253–320. 1899–1906: Untersuchungen über Aminosäuren, Polypeptide und Protein. (Book) Berlin, 1906. 1901, i: Ueber die Hydrolyse des Caseins durch Salzsäure. *Zeit. physiol. Chem.* **33**, 151–176. 1901, ii: Ueber die Entstehung von α-Pyrrolidincarbonsäure und Phenylalanin bei der Hydrolyse des Eieralbumins. *Zeit. physiol. Chem.* **33**, 412–416.

Fischer, E., and Abderhalden, E., 1903: Ueber die Verdauung einiger Eiweisskörper durch Pancreasfermente. *Zeit. physiol. Chem.* **39**, 81–94.

Fletcher, F., 1910: Effects of previous heating of the soil on the growth of plants and the germination of seeds. *Cairo Scientific Journal* **4**, 81–86.

Fosse, R., 1916: Origine et distribution de l'urée dans la nature. Application de nouvelles méthods d'analyse d'urée basées sur l'emploi du xanthydrol. Cinquième Partie. L'urée chez les végétaux. *Ann. chim. N. S.* **6**, 198 (1916).

Frank, B., 1888: Ueber die physiologische Bedeutung der Mycorhiza. *Ber. Bot. Ges.* **6**, 248–269.

Gortner, R. A., 1916: The origin of the humin formed by the acid hydrolysis of proteins, ii: Hydrolysis in the presence of carbohydrates and aldehydes. *J. Biol. Chem.* **26**, 177–204.

Gortner, R. A., and Blish, M. J., 1915: On the origin of the humin formed by the acid hydrolysis of proteins. *J. Amer. Chem. Soc.* **37**, 1630–1636.

Grindley, H. S., and Slater, M. E., 1915: The quantitative determination of the amino acids of feeding stuffs by the Van Slyke method. *J. Amer. Chem. Soc.* **37**, 2762–2769.

Grouven, 1883: *Jahresber. Fort. Agr. Chem.* p. 19.

Gulewitsch, W., 1899: Ueber das Arginin. *Zeit. physiol. Chem.* **27**, 178–215.

Hartwell, B. L., and Pember, F. R., 1912: The effects of the "Wet Process" on the availability of the low grade nitrogenous materials. *J. Ind. Eng. Chem.* **4**, 441–443.

Hasenbrock, K., 1888: Ueber das Schicksal des Lecithins im Körper und eine Beziehung desselben zum Sumpfgas im Darmcanal. *Zeit. physiol. Chem.* **12**, 148–162.

Hausmann, W., 1899: Ueber die Vertheilung des Stickstoffs im Eiweissmolekül. *Zeit. physiol. Chem.* **27**, 95–108.

Hedin, S. G., 1895: Eine Methode, das Lysin zu isoliren, nebst einigen Bermerkungen über das Lysatinin. *Zeit. physiol. Chem.* **21**, 297–305.

Herbert, 1889: De la formation de l'ammoniaque dans la terre arable. *Ann. agron.* **15**, 355–363.

Herlant, L., 1900: Untersuchungen über die Nucleinsäure aus unreifer Lachsmilch, aus Kalbsthymus und aus Hefe. *Arch. expt. Pathol.* **44**, 148–159.

Hiltner, L., and Störmer, K., 1903: Studien über die Bakterienflora des Ackerbodens, mit besonderer Berüchsichtung ihres Verhaltens nach einer Behandlung mit Schwefelkohlenstoff und nach Brache. *Arbeit Biol. Abt. Landw. Fortwirtschaft* **5**, 445–545.

Hofmeister, F., 1887. Beiträge zur Kentniss der Amidosäuren. *Liebig's Ann.* **189**, 6–43. 1902: Ueber Bau und Gruppierung der Eiweisskörper. *Ergeb. d. Physiol.* **1**, i. Abt. 759–802.

Hoppe-Seyler, F., 1876: Ueber die Process der Gährungen und ihre Beziehung zum Leben der Organismen. *Pflüger's Arch. g. Physiol.* **12**, 1–17. 1877: Weitere Mittheilungen über die Eigenschaften des Blutfarbstoffs. *Zeit. physiol. Chem.*, 121–139. 1878: Ueber Gährungprozesse. *Zeit. physiol. Chem.* **2**, 1–28.

Hutchinson, H. B., and Miller, N. H. J., 1911: The direct assimilation of inorganic and organic forms of nitrogen by higher plants. *Centralb. Bakt. Parasitenk.* **30**, 513.

Iwanoff, L., 1903: Ueber die fermentative Zersetzung der Thymonucleinsäure durch Schimmelpilze. *Zeit. physiol. Chem.* **39**, 31–43.

Jodidi, S. L., 1909: Organic nitrogenous compounds in peat soils. *Tech. Bul.* **4**, Mich. Agr. Expt. Sta. 1911, i: The chemical nature of the organic nitrogen in the soil. *Research Bul.* **1**, Iowa State Agr. Expt. Sta. 1911, ii: The chemical nature of the organic nitrogen in the soil, ii. *Research Bul.* **3**, Iowa State Agr. Expt. Sta. 1912: Amino acids and acid amides as sources of ammonia in soils. *Research Bul.* **9**, Iowa State Agr. Expt. Sta.

Jost, L., 1900: Die Stickstoffassimilation der grünen Pflanzen. *Biolog. Centralb.* **20**, 625–637.

Kasaroff, P., 1906: Gleichzeitung ein Beitrag zur Kentniss durch Sterilisation herbeigeführten Veränderungen des Bodens. *Arb. Kais. Biol. Anstalt Landw. Fortwirtschaft* **5**, *Heft* 3, 126–138.

Kelly, W. P., 1914: The organic nitrogen of Hawaiian Soils, ii. The effects of heat on soil nitrogen. *J. Amer. Chem. Soc.* **36**, 434–438. 1915: The Biochemical decomposition of nitrogenous substances in soils. *Bul.* **39**, Hawaii Agr. Expt. Sta.

Kelly, W. P., and McGeorge, Wm., 1913: The effects of heat on Hawaiian soils. *Bul.* **30**, *Hawaii Agr. Expt. Sta.*

Kelly, W. P., and Thompson, A. R., 1914: The organic nitrogen of Hawaiian soils. *Bul.* **33**, Hawaii Agr. Expt. Sta.

Kerry, R., 1889: Ueber die Zersetzung des Eiweisses durch die Bacillen des Malignen Oedems. *Monatshefte Chem.* **10**, 864–873.

Kiesel, A., 1909: Autolytische Argininzersetzung in Pflanzen. *Zeit. physiol. Chem.* **60**, 460–461.

Klaproth, 1883: *De Candolle, Pflanzen Physiologie*, i, 279.

Kober, P. A., and Sugiura, K., 1913: A microchemical method for the determination of α- and β-amino acids and certain derivatives in proteolysis, blood, and urine. *J. Amer. Chem. Soc.* **35**, 1546–1585.

Koch, A., and Lüken, G., 1907: Ueber die Veränderung eines leichten Sand-Bodens durch Sterilisation. *Jour. f. Landw.* **55**, 161–172.

König, J., Hasenbäumer, J., and Coppenrath, E., 1906: Einige neue Eigenschaften des Ackerbodens. *Landw. Vers. Stat.* **63**, 471–478. 1907: Beziehung zwischen den Eigenschaften des Bodens und der Nahrstoffaufnahme durch die Pflanzen. *Landw. Vers. Stat.* **66**, 401.

Kossel, A., 1886: Weitere Beiträge zur Chemie des Zellkerns. *Zeit. physiol. Chem.* **10**, 248–272. 1896: Ueber die basischen Stoffe des Velkerns. *Zeit. physiol. Chem.* **22**, 182–187. 1898: Ueber die Constitution der einfachsten Eiweisskörper. *Zeit. physiol. Chem.*, **25**, 165–189. 1899: Ueber die Darstellung und den Nachweiss des Lysins. *Zeit. physiol. Chem.* **26**, 585–587.

Kossel, A., and Dakin, H. D., 1904: Ueber Arginase. *Zeit. physiol. Chem.* **41**, 321–331.

Kossel, A., and Kutscher, F., 1900: Beiträge zur Kenntniss der Eiweisskörper. *Zeit. physiol. Chem.* **31**, 165–214.

Kossel, A., and Matthews, A., 1898: Zur Kenntniss der Trypsinwirkung. *Zeit. physiol. Chem.* **25**, 190–194.

Kossel, A., and Steudel, H., 1903: Weitere Untersuchungen über das Cytosin. *Zeit. physiol. Chem.* **38**, 49–59.

Kossowicz, A., 1912: Die Zersetzung von Harnstoff, Harnsäure, Hippursäure, und Glycocoll durch Schimmelpilze. *Z. Gärungsphysiol.* **1**, 60–62. 1913, i: Nitritassimilation durch Schimmelpile. *Z. Gärungsphysiol.* **2**, 55–58. 1913, ii: Die Assimilation von Guanin und Guanidin durch Schimmelpilze. *Z. Gärungsphysiol.* **2**, 84–86. 1914: Zur Kenntniss der Assimilation von Kohlenstoff- und Stickstoffverbindungen durch Schimmelpilze. *Biochem. Ztschr.* **67**, 391–399.

Kruse, Walter, 1910: Allgemeine Mikrobiologie, Chapter IX. (Book) Leipzig.

Laidlaw, W., and Price, C. A., 1910: Sterilization of soils. *Jour. Dept. Agr. Victoria* **8**, 365–368.

Lathrop, Elbert C., 1912: Guanine from a heated soil. *J. Amer. Chem. Soc.* **34**, 1260–1263. 1914: The nitrogen of processed fertilizers. *Bul.* **158**, U. S. Dept. Agr. 1916: Protein decomposition in soils. *Soil Science*, **1**, 509–532.

Lathrop, E. C., and Brown, B. E., 1911: Studies in organic soil nitrogen. *J. Ind. Eng. Chem.* **3**, 657–660.

Lemmermann, O., Fischer, H., Kappen, H., and Blanck, E., 1909: Bakteriologische-Chemische Untersuchung. *Landw. Jahrb.* **38**, 319–364.

Levene, P. A., 1910: Partielle Hydrolyse der Nucleinsäuren. *Abderhalden's Handb. Biochem. Arbeitsm.* ii, 605–609. 1911: Partielle Hydrolyse der Nucleinsäuren. *Abderhalden's Handb. Biochem. Arbeitsm.* v, 489–499.

Levene, P. A., and Jacobs, W. A., 1908: Ueber die Inosinsäure. *Ber.* **41**, 2703–2707. 1910: Ueber das Vorkommen des freien Guanosins in der Pancreasdrüse. *Biochem. Ztschr.* **28**, 127–130.

Levene, P. A., and Jacobs, W. A., 1911: Ueber die Inosinsäure. *Ber.* **44**, 746–753.

Levene, P. A., and LaForge, F. B., 1912: Ueber die Hefe-Nucleinsäure v. Die Struktur der Pyrimidin-Nucleoside. *Ber.* **45**, 608–620.

Levene, P. A., and Medigreceanu, F., 1911, i: On nucleases. *J. Biol. Chem.* **9**, 65–83. 1911, ii: The action of gastro-intestinal juices on nucleic acids. *J. Biol. Chem.* **9**, 375–387. 1911, ii: On nucleases. *J. Biol. Chem.* **9**, 389–402.

Liebscher, 1893: Welche Kulturpflanzen vermehren den Stickstoff-Vorrat der Wirtschaft, ii. Die Stickstoffsammelung der Kulturpflanzen. *Deut. Landw. Presse* **20**, 975–6.

Lilienfeld, L., 1892: Ueber den flussigen Zustand des Blutes und die Blutgerinnung. *Arch. f. Anat. Physiol.* (1892), p. 550.

Lipman, J. G., Brown, P. S., and Owen, I. L., 1911–1912: The availability of nitrogenous materials as measured by ammonification. *Centralb. Bakt. Parasitenk.* **31**, ii. Abt. 49–85.

Loew, O., 1909: Soil Disinfection in Agriculture. *Porto Rico Expt. Sta. Cir.* **11**, 1909.

Loew, O., and Aso, K., 1907, i: On changes of availability of nitrogen in soils, i. *Bul. Coll. Agr. Tokio* **7**, 443–448. 1907, ii: On changes of availability of nitrogen in soils, ii. *Bull. Coll. Agr. Tokio* **7**, 567–574.

Loges, G., 1886: Ueber stickstoffhaltige organische Verbindungen in der Ackererde. *Landw. Vers. Stat.* **32**, 201–202.

Lyon, T. L., and Bizzell, J. A., 1909, i: Changes produced in soils by subjecting them to steam under pressure. *J. Soc. Chem. Ind.* **28**, 721. (abs.) 1909, ii: Effects of steam sterilization on the water soluble matter of soils. *Bul.* **275**, Cornell Agr. Expt. Sta.

Lyon, T. L., and Bizzell, J. A., 1913: Water soluble matter in soils sterilized and reinoculated. *Bul.* **326**, Cornell Agr. Expt. Sta.

Maillard, L. C., 1913: Genèse des matières protéiques et des matières humiques, action de la glycerine et des sucres sur les acides α-amiés (Book) Paris, 1913, p. 432.

Malaguti, M., 1835: Action des Acides etendus sur les Sucre. *Ann. Chim. phys.* **59**, 407–423.

May, 1898: Sterilizing soil for destroying eel worms. *Amer. Florist* **13**, 721.

Mitcherlich, E.: *Lehrbuch der Chemie*, 3rd edit., i, p. 543.

Müntz. A. and Coudon, H., 1893: La fermentation ammoniacale de la terre. *Compt. rend.* **116**, 395–398.

Mulder, G. J., 1840: Untersuchungen über die Humussubstanzen. *J. prakt. Chem.* **21**, 321–370; also 203–240. 1844: Ueber die Besthandtheile der Ackerboden. *J. prakt. Chem.* **32**, 321–354. 1862: Chemie der Ackerkrume. (Book) Berlin, 1862.

Nakayama, M., 1904: Ueber das Erepsin. *Zeit. physiol. Chem.* **41**, 348–362.

Nawaiasky, P., 1908, i: Ueber die Ernährung einiger Spaltpilze in peptonhaltigen Nährböden. *Arch. Hyg.* **64**, 33–61. 1908, ii: Ueber die Umsetzung von Aminosäuren durch Bac. proteus vulgaris. *Arch. Hyg.* **66**, 209–243.

Neubauer, O. and Fromherz, K., 1911: Ueber den Abbau der Aminosäuren bei Hefegärung. *Zeit. physiol. Chem.* **70**, 326–350.

Neuberg, C. and Capezzuoli, C., 1909: Biochemische Umwandlung von Asparagin und Asparaginsäure in Propionsäure und Bernsteinsäure. *Biochem. Ztschr.* **18**, 424–434.

Nollau, E. H., 1915: The amino acid content of certain commercial feeding stuffs and other sources of protein. *J. Biol. Chem.* **21**, 611.

Omelianski, W. L., and Sieber, N. O., 1913: Zur Frage nach der chemischen Zusammensetzung der Bakterienkörper des Azotobacter chroococcum. *Zeit. physiol. Chem.* **88**, 445–459.

Osborne, T. B., and Harris, I. F., 1902: Die Nucleinsäure des Weizenembryos. *Zeit. physiol. Chem.* **36**, 85–133. 1903: Nitrogen in protein bodies. *J. Amer. Chem. Soc.* **25**, 323–353.

Osborne, T. B., and Heyl, F. W., 1908, i: Hydrolysis of chicken meat. *Amer. J. Physiol.* **22**, 433–439.

Osborne, T. B., Leavenworth, C. S., and Brautlecht, E. A., 1908, ii: The different forms of nitrogen in proteins. *Amer. J. Physiol.* **23**, 180–200.

Osborne, T. B., and Heyl, F. W., 1908, iii: Hydrolysis of Legumelin from the pea. *J. Biol. Chem.* **5**, 197–205.

Osborne T. B., and Jones, D. B., 1909: Hydrolysis of ox muscle. *Amer. J. Physiol.* **24**, 437–446.

Peterson, P. T., 1911: Effect of heat and oxidation on the phosphorus of the soil. *Research Bul.* **9**, Univ. Wisc. Agr. Expt. Sta.

Pfeiffer, Th., and Franke, E., 1896: Beitrage zur Frage der Verwertung elementaren Stickstoffs durch den Senf. *Landw. Vers. Stat.* **46**, 117–151.

Pfeiffer, Th., Frank, L., Friedlander, K., and Ehrenberg, P., 1909: Stickstoff Haushaltung der Ackerboden. *Mitt. Landw. Inst. Breslau* **4**, 773–779.

Pfeiffer, Th., Guttermann, A., and Theile, F., 1910: Der Stickstoff-Haushalt des Ackerbodens. *Mitt, Landw. Inst. Breslau* **5**, 657–713.

Pickering, S. U., 1908, i: Studies on germination and plant growth. *J. Agr. Science* **2**, 411–434. 1908, ii: On the action of heat and antiseptics on soils. *J. Agr. Science* **3**, 32–54.

Piria, R., 1852: Notiz über das Tyrosins. *Liebig's Ann.* **82**, 251–252.

Potter, R. S., and Snyder, R S., 1915, i: Amino acid nitrogen of soil and the chemical groups of amino acids in the hydrolysed soils and their humic acids. *J. Amer. Chem. Soc.* **37**, 2219–2227. 1915, ii: The amino acid in nitrogen of soil. *J. Ind. Eng. Chem.* **7**, 1049–1053.

Reisser, O., 1913: Theoretisches und Experimentalles zur Frage der Kreatinbildung im tierischen Organismus. *Zeit. physiol. Chem.* **86**, 415–453. 1914. Weitere Beiträge zur Frage der Kreatinbildung aus Cholin und Betain. *Zeit. physiol. Chem.*, **90**, 221–235.

Reed, H. S., and Williams, B., 1915: The effects of some organic soil constituents upon nitrogen fixation by azotobacter. *Centralb. Bakt. Parasitenk.* **43**, ii. Abt. 166–176.

Ritthausen, 1880: Ueber den Stickstoffgehalt des Torfbodens. *Landw. Vers. Stat.* **25**, 169–171.

Richter, L., 1896: Ueber die Veränderungen welche der Boden durch das Sterilisieren erleidet. *Landw. Vers. Stat.* **47**, 269–274.

Robinson, C. S., 1911: Organic nitrogenous compounds in peat soils, ii. *Tech. Bul.* **7**, Mich. Agr. Expt. Sta.

Roxas, M. L., 1916: The reaction between amino-acids and carbohydrates as a probable cause of humin formation. *J. Biol. Chem.* **27**, 71–93.

Ruata, G. Q., and Caneva, G., 1901: Della scompositizione della lecitine contributo allo studio della putrifazione e della diagnosi. *Annali d'igiene (Roma) N. S.*, ii, 341–345.

Rudd, 1893: Killing grubs in soil. *Amer. Florist* **9**, 171.

Russell, E. J., 1910: Factors which determine fertility in soils. *Science Progress* **4**, 353–365.

Russell, E. J., and Hutchinson, H. B., 1909: The effects of partial sterilization of soil on the production of plant food. *J. Agr. Sci.* **3**, 111–144.

Russell, E. J., and Petherbridge, F. R., 1912: Partial Sterilization of soil for greenhouses. *Pharm. J.* **88**, 286–287. 1912–1913: The growth of plants in partially sterilized soils. *J. Agr. Sci.* **5**, 248–287.

Sachs, 1905: Ist die Nuclease mit dem Trypsin identisch? *Diss Heidelberg.*

Sasaki, T., 1912, i: Ueber den Abbau einiger Polypeptide durch Bakterien. Untersuchungen mit nicht verflüssigenden Bakterien. *Biochem. Ztschr.* **47**, 462–471. 1912, ii: Ueber den Abbau einiger Polypeptide durch Bakterien. Untersuchungen mit verflüssigenden Bakterien. *Biochem. Ztschr.* **47**, 474–481.

Schittenhelm, A., and Schröter, F., 1904: Ueber die Spaltung der Hefnucleinsäure. *Zeit. physiol. Chem.* **41**, 284–292.

Schittenhelm, A., 1909: Ueber die Fermente des Nucleinstoffwechsels in Lupinenkeimlingen. *Zeit. physiol. Chem.* **63**, 289.

Schmeideberg, O., 1899: Ueber die Nucleinsäure aus Lachsmilch. *Arch. expt. Pathol.* **43**, 57–83.

Schmoeger, M., 1893: Ueber das Phosphor im Moorboden. *Ber.* **26**, 386–394.

Schmuk, 1914: Einige Daten zur Frage über die Formen des Stickstoffs in Boden. *Russ. J. Expt. Landw.* **15**, 139–153.

Schreiner, Oswald, Reed, H. S., and Skinner, J. J., 1907: Certain organic constituents of soils in relation to soil fertility. *Bul.* **47**, Bureau of Soils, U. S. Dept. Agr.

Schreiner, O., and Shorey, E. C., 1909: The isolation of harmful organic substances from soils. *Bul.* **53**, Bureau of Soils, U. S. Dept. Agr. 1910: The chemical nature of soil organic matter. *Bul.* **74**, Bureau of Soils, U. S. Dept. Agr.

Schreiner, O., and Lathrop, E. C., 1911: The distribution of organic constituents in soils. *J. Frank. Inst.* **172**, 145–151. 1912: The chemistry of steam-heated soils. *J. Amer. Chem. Soc.* **34**, 1242–1259.

Schreiner, O., and Skinner, J. J., 1912: Nitrogenous soil constituents and their bearing on soil fertility. *Bul.* **87**, Bureau of Soils, U. S. Dept. Agr.

Schreiner, O., and Brown, B. E., 1912: Occurrence and nature of carbonized material in soils. *Bul.* **90**, Bureau of Soils, U. S. Dept. Agr.

Schultz, E., and Libiernik, A., 1891: Ueber die Bildung von Harnstoff bei der Spaltung des Arginins. *Ber.* **24**, 2701–2704.

Schultz, E., and Winterstein, E., 1897: Ueber ein Spaltungprodukt des Arginins. *Ber.* **30**, 2879–2882. 1898: Ueber die Bildung von Orithin bei der Spaltung des Arginins und über die Constitution dieser beiden Basen. *Zeit. physiol. Chem.*, **26**, 1–14.

Schulze, C., 1903: Einige Beobachtungen über die Einwirkung der Bodensterilisation auf die Entwicklung der Pflanzen. *Jahresber. Ver. Vertreter angew. Bot.* **1**, 37–44.

Schwanert, H., 1857: Ueber einige Zersetzungen des Leucins. *Liebig's Ann.* **102**, 221–236.

Schwantke, A., 1900: Zur Krystallform des Histidindichlorids. *Zeit. physiol. Chem.* **29**, 492.

Seaver, F. J., 1909: Studies in Pyrophilous fungi, i. The occurrence and cultivation of pyronema. *Mycologia* **2**, 131–139.

Seaver, F. J., and Clark, E. D., 1910: Changes brought about by the heating of soils and their relation to the growth of pyronema and other fungi. *Mycologia* **2**, 109–124.

Selby, A. D., 1896: Investigations of plant diseases in forcing house and garden. *Bul.* **73**, 221–245, Ohio Agr. Expt. Sta.

Sestini, F., 1899: Der die Humussäure im Erdreich und Torfe Begleitende Stickstoffgehalt. *Landw. Vers. Stat.* **51**, 153–158.

Shorey, E. C., 1905: Report of Chemist, Agr. Invest. Hawaii in 1905. 1906: Report of Chemist, Agr. Invest. Hawaii in 1906: 1912, i: The isolation of creatinine from soils. *J. Amer. Chem. Soc.* **34**, 99–107. 1912, ii: Nucleic acids in soils. *Science* **35**, 390. 1913: Some organic soil constituents. *Bul.* **88**, Bureau of Soils, U. S. Dept. Agr.

Shorey, E. C., and Walters, E. H., 1914: A nitrogenous soil constituent, Tetracarbonimid. *J. Agr. Research* **3**, 175–178.

Siegfried, M., 1905: Ueber die Bindung von Kohlensäure durch amphotere Amidokörper. *Zeit. physiol. Chem.* **44**, 85–96. 1908: Isolation of glycine, albumoses or peptones from dilute aqueous solutions. *J. Chem. Soc.* 1908, i, 234 (abs.).

Simon, M. E., 1875: Untersuchungen über die Zusammensetzung der natürlichen Humussäure, ihre Betheilung an der Pflanzennährung und ihre Vereinigung mit den Mineralstoffen. *Bied. Centrlb.* **8**, 74–79.

v. Sivers, M., 1880: Ueber den Stickstoffgehalt des Torfbodens. *Landw. Vers. Stat.* **24**, 183–210.

Skinner, J. J., 1911: Effects of creatinine on growth and absorption. *Bul.* **83**, iii, *Bureau of Soils*, U. S. Dept. Agr.

Sörenson, S. P. L., 1907: Enzymstudien. *Biochem. Ztschr.* **7**, 45–101.

Sprengel, K., 1826: *Erdmann's Jour. f. tech. u. ökon. Chem.* **10** (1831).

Stone and Smith, 1901: Report of the Botanists, Mass. Agr. Expt. Sta. 1902: Report of the Botanists, Mass. Agr. Expt. Sta.

Stone and Monohan, 1904: Report of the Botanists, Mass. Agr. Expt. Sta.

Stuart, Wm., 1905: Soil Sterilization. 18th Ann. Rpt. Vermont Agr. Expt. Sta.

Suzuki, S., 1907: Studies on Humus formation, iii. *Bul. Coll. Agr. Tokio* **7**, 513–529.

Thompson, 1840: Untersuchungen über die Humussubstanzen. *J. prakt. Chem.* **21**, 325.

Trescot. T. C., 1913: Comparison of the Kjeldahl-Gunning-Arnold method with the official Gunning method for the determination of nitrogen. *J. Ind. Chem.* **5**, 914–915.

Twort, F. W, and Mellanby, E., 1912: On creatin-destroying bacilli in the intestine and their isolation. *J. Physiol.* **44**, 43–49.

Ulipiani, C., and Cingolani, E., 1905: Sulla fermentazione della guanina. *Rendic. Acc. Lincei* (5) **14**, 596–600.

Van Slyke, D. D., and Birchard, F. J., 1913: The nature of the free amino groups in proteins, *J. Biol. Chem.* **16**, 539–547.

Van Slyke, D. D., 1911: The analysis of proteins by determination of the chemical groups characteristic of the different amino acids. *J. Biol. Chem*, **10**, 15–55. 1912: Quantitative determination of aliphatic amino groups, ii. *J. Biol. Chem.* **12**, 275–284. 1915: Improvement in the method for analysis of proteins by determination of the chemical groups characteristic of the different amino acids. *J. Biol. Chem.* **22**, 281–285.

Vogel, J., 1914: Beitrag zum Verhalten durch Erhitzen Sterilisierten Erde. *Centrlb. Bakt. Parasitenk*, **40**, ii. Abt. 280–284.

Walters, E. H., 1915: The presence of proteoses and peptones in soils. *J. Ind. Eng. Chem.* **7**, 860.

Warington, 1887: Some recent researches on the nature of the nitrogenous organic matter of soils. *Chem. News* **55**, 27–28.

Wilson, G. W., 1914: Studies on Plant Growth in heated soil. *Biochem. Bul.* **3**, 202–209.

Wise, L. E., and Walters, E. H., 1917: Isolation of Cyanuric Acid from Soil. *Jour. Agr. Research.*

Wulff, C., 1893: Beiträge zur Kenntniss der Nucleinbasen. *Zeit. physiol. Chem.* **17**, 468–510.

Wurster, C., 1889: Chinon als Reagens auf Aminosäuren, besonders Leucin und Sarkosin, *Centrlb. Physiol.* **2**, 590–591.

Zaleski, W., and Pjukow, D., 1914: Ueber Elektion der Stickstoffverbindungen durch Aspergillus. *Ber. deut. Botan. Ges.* **32**, 479–483.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE NATURE AND SPEED OF FLASHPOWDERS.[1]

By John I. Crabtree.

[ABSTRACT.]

A FLASHPOWDER consists of a combustile metal, such as magnesium or aluminum, together with a suitable oxidizing agent, and usually other agents which may accelerate or retard the combustion of the metal, or modify the color of the light produced.

The excellence of any flashpowder is determined by the actinic value of the flash, the amount of noise and smoke produced, immunity of the same to friction or percussion, the nature of the spectrum produced, and the speed of combustion of the powder.

The latter may be easily determined by photographing a sheet of ground glass, illuminated from behind by the flash, by means of a motion-picture camera taking 32 or more pictures per second. The number of images obtained on the film is a direct measure of the speed, while by plotting the densities of each picture a time-intensity curve is obtained. The light intensity usually attains a maximum almost immediately, and then fades away gradually. The effective speed is usually only about half that indicated by the above method, since the photographic effect produced during the latter periods of the flash is almost neglible.

The particular speed of a powder is determined by the composition and fineness of division of the constituents, the quantity and age of the powder used, and the method of igniting the same.

In taking portraits, it is important to eliminate blinking and an unnatural expression of the sitter. Blinking may be avoided by using a powder whose speed of combustion is faster than the time of reflex action of the eye. In this way the portrait is taken before the blink occurs, an effective speed of one-twelfth of a second being usually sufficient to prevent this blinking.

The unnatural expression observed in many flashlight por-

* Communicated by the Director.

[1] Communication No. 43 from the Research Laboratory of the Eastman Kodak Company, published in *British Journal of Photography*, January 19, 1917, p. 29.

traits is due to an excessive dilation of the eye-pupils caused by the low light intensity prevailing when the portrait was taken. By focusing under a light whose intensity approaches that of weak daylight, the eye-pupils assume their natural size and a natural expression is thereby obtained.

STELLAR IMAGES ON A PHOTOGRAPHIC PLATE AS AFFECTED BY DEVELOPMENT.[1]

By F. E. Ross.

[ABSTRACT.]

A PRELIMINARY investigation of a two-fold nature: (*a*) determination of differences in power, if any, of various developers in developing faint stellar images; (*b*) determination of differences in quality, if any, of stellar images, depending upon the developer, with special reference to the accuracy of measurement of their distance apart on the plate.

The tests were made by photographing a series of small, round holes in a plate. Under (*a*) above, no certain differences were detected. In investigating (*b*) pyro and caustic hydrochinon (process developer) were tried, development being carried to two and four minutes. From the measurement of 320 distances between images it was establishd that greater accuracy in measurement was secured where the process developer was used; that the lighter development gave best results. This superiority was anticipated, since the appearance of the images was decidedly better for short development in process developer than for any other of those tried.

THE FUNDAMENTAL SCALE OF PURE HUE AND RETINAL SENSIBILITY TO HUE DIFFERENCES.[2]

By L. A. Jones.

[ABSTRACT.]

WHEN radiant energy is incident upon the retina of a normal eye the sensation of light is produced. This sensation may be said to consist of two factors, brightness and color, the former

[1] Communication No. 47 of the Research Laboratory of the Eastman Kodak Company, published in *Journal, Optical Society of America*, January, 1917.

[2] Communication No. 44 of the Research Laboratory of the Eastman Kodak Company, published in *Journal, Optical Society of America*, January, 1917.

being dependent upon the intensity and the latter upon the quality of the incident radiation. The quality of the radiation may be specified by stating its wave-length, in case radiation of but one frequency is present; or, in case it is composed of a mixture of many frequencies, by stating the wave-length and intensity of each of the component elements. The curve representing the relations existing between the intensity and wave-length of such mixed radiation, commonly called a spectrophotometric curve, is usually plotted with intensity factors as ordinate and wave-lengths as abcissa values.

Such a curve constitutes a complete physical specification of the quality of the radiation, and hence of color. The retina, however, being a synthetic rather than an analytic receiving organ, does not recognize the individual component parts of the radiation as such, but receives the mixed radiation as a single stimulus producing a single color sensation. Hence a spectrophotometric curve, while entirely satisfactory from a physical or objective standpoint, does not constitute a physiological specification of the color of the visible radiation, and it is necessary to provide other means for the satisfactory specification of color as such.

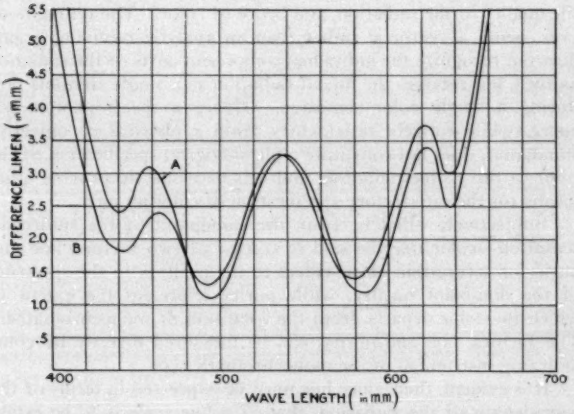
Subjectively—that is, from the standpoint of the subjective sensation—color may be said to consist of two factors, hue and purity or saturation. Hue refers to the position in the spectrum of the dominant quality, while purity expresses the extent to which the color departs from the condition of monochromatism. The factors, hue and purity, can be measured directly by color molyzing instrument of the monochromatic type.

It is evident, then, since hue must be expressed in terms of the wave-length of the radiation, that, if a hue scale is to be established, the points on that scale must be designated in wave-length units. The first requirement of a scale for the measurement of any quantity is that the unit used shall be of a fixed magnitude and of the same value throughout the scale. It has been found, however, that equal wave-length differences do not produce equal color sensation differences throughout the sensation scale being considered. Hence the wave-length unit is not suitable for use as a unit in the establishment of a scale of subjective color sensation.

It seems to be most logical, therefore, and in fact the only alternative, to adopt as the unit for such a scale the least percepti-

ble color sensation difference, and to assume that this sensation unit (difference limen) is equal at all points in the sensation scale. The question as to whether or not the difference limen is equal at all points on any sensation scale has been discussed at great length by philosophers and psychologists, and seems to be capable of settlement in either direction by the proper course of metaphysical reasoning. However, from the standpoint of a physicist, it seems entirely reasonable to make the difference limen at all points on a sensation scale equal by definition and to adopt

FIG. 1.



this least perceptible difference as a sensation unit and to use it for the establishment of sensation scales.

The first step, then, in the establishment of the fundamental hue scale is the determination of precise values (in terms of wave-length units) for the average normal human eye of the least perceptible hue differences (the sensation unit) throughout the visible spectrum. The final values, then, must be the result of the proper summarization of a large amount of data obtained from the study of a large number of different individuals having normal vision.

Steindler[1] has made measurements on the hue sensibility of twelve subjects, all having normal color vision. It seemed desirable to obtain further data on difference limen of other individuals, and for this purpose the following work was carried out. The measurement of the required difference limen involves the measurement of the difference in the wave-length of the light illuminating two fields which appear just perceptibly different in hue; since the desired scale is that of pure hue, fields illuminated by light as nearly monochromatic as possible must be used. Hence apparatus giving very pure monochromatic light of easily measurable and variable wave-length in connection with some type of two-part photometer field, each part of which may be illuminated independently by monochromatic light of variable quality and intensity, must be employed. It is very important that the intensity be easily controllable, for in making a judgment of equality or difference of hue it is necessary to maintain an intensity balance between the two fields in order that the judgment of hue may not be influenced or confused by the existence of an intensity difference. The first instrument constructed for the fulfilment of these conditions is shown diagrammatically in Fig. 3.

The determination of the difference limen was accomplished by adjusting the angular positions of the two collimating systems, O_1L_1 and O_2L_2, until a just perceptible difference in hue was apparent between the two portions, a,a[1] and b, of the photometric field, and by then obtaining the wave-length difference from readings taken from the calibrated scales, B_1 and B_2. The value thus obtained gave the difference limen for a point in the spectrum midway between the two wave-length values read from the calibrated scales. Several readings were made at each point and at many different points throughout the visible spectrum, a difference limen-wave-length curve being plotted from the values thus obtained.

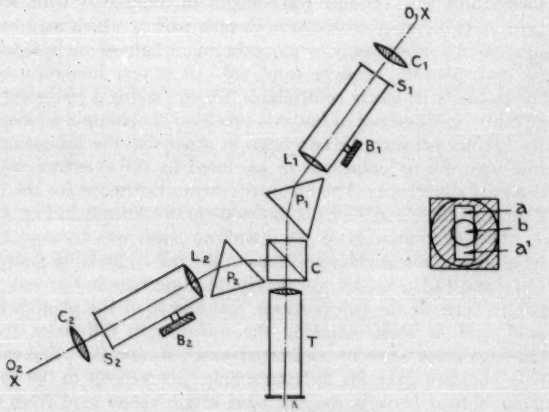
Many data were obtained with this instrument, which in many ways was found to be very satisfactory, but, due to certain mechanical defects, this was discarded and the work continued with improved apparatus. This consisted of a Brace spectrophotometer used in connection with a Hilger spectroscope of the constant-deviation type. This arrangement permitted of much higher

[1] Steindler, O., *Ak. Wiss. Wien.*, 115 IIa Jan., 1906.

precision in the measurement of the wave-length of the light illuminating the two parts of the photometric field at any time, and also made it possible to set the two fields to an exact color match by means other than the visual judgment of hue.

In Fig. 5 are shown two complete limen curves, curve A being plotted from data obtained with the first instrument and curve B from limen data taken with the Brace-Hilger apparatus. These curves agree very well in shape and in magnitude of the limen values. They also agree quite well with Steindler's mean curve

FIG. 3.



(Fig. 1), showing the same typical maxima and minima. The limen values agree fairly well with those of Steindler except in the blue end between 400 μμ and 470 μμ. This lack of agreement will be mentioned again later in the discussion.

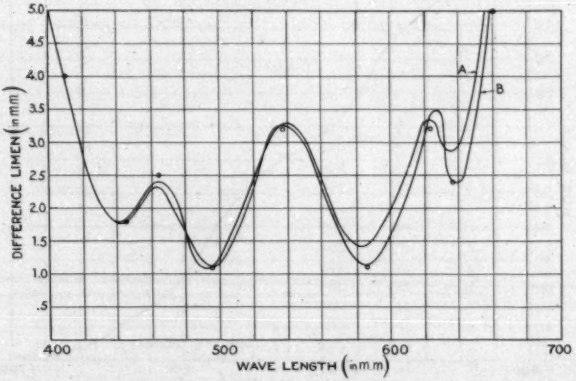
The mean curve obtained by averaging the three sets of data obtained with the right eye is shown as curve B, Fig. 1, in order that its shape and the magnitude of the limen values may be easily compared with the mean of Steindler's data. It will be noted that the values of curve B agree very well with those of A from about 470 to 580 μμ, and that in the red and yellow from 580 to 660 the curve B shows limen values only slightly less than those of A. In the blue end, however, from 410 to 470 the limen

values of B are considerably less than those of A. The positions in the spectrum of the various maxima and minima are nearly the same in the two curves.

The results so far indicate that an observer can repeat results on hue limen fairly well, and that the limen-wave-length curve for an individual has a very definite shape.

Now, referring to the scale reading curve, plotted from these same values, in Fig. 6, suppose that a series of points separated by equal intervals be laid off on the hue scale (y axis) and a series of horizontal lines be drawn through these points cutting the scale-reading curve. Now the wave-length values obtained by projecting these points of intersection on the wave-length axis

FIG. 5.



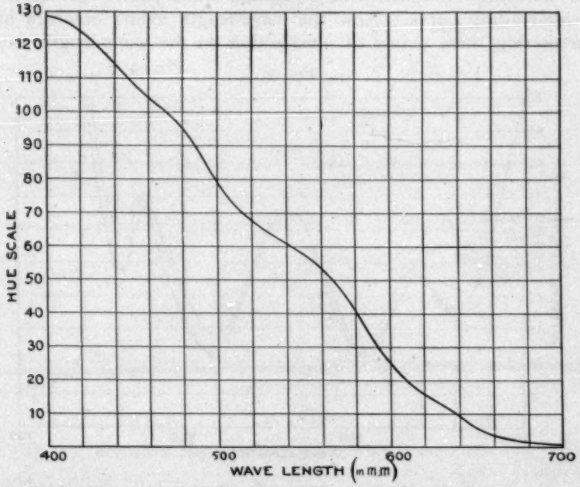
(x axis) will represent a series of spectral hues separated by equal sensation steps. Or, by the inverse process, starting with the wave-length values, it is easy to determine whether any series of hues are separated by equal or unequal sensation steps.

This method of analysis has been applied to one of the best systems of color standards. This system was devised and worked out by Robert Ridgway, Curator of the Division of Birds, United States National Museum, and is described in detail and illustrated with 1115 named color standards in his book, "Color Standards and Nomenclature." The system is based on the correct princi-

ple of adopting both hue and purity scales based on equal sensation intervals. The scale of pure (spectral) hue consists of 30 units in the visible spectrum, separated by equal sensation intervals, and 6 units spaced through the purples (not present in the spectrum).

In order to determine the spacing on the sensation scale of these 36 hue scale units, it was necessary to measure the dominant hue of each. The actual samples used were cut from sheets ob-

FIG. 6.



tained from the publisher, and it is entirely possible that some of these may differ slightly from those issued in Mr. Ridgway's book.

The colorimetric analyses of the 36 color standards of the hue scale are given in Table I (p. 507). They are numbered (column 1) consecutively, starting with the reddest red and ending with the reddest purple. The names (column 2) are those proposed by Ridgway. The dominant hue values (column 3) are in milli-microns ($\mu\mu$) and the purity values (column 4) are in per cent. white or

per cent. hue. In column 5 are given the wave-length intervals, $d\lambda$ (in $\mu\mu$), between the successive samples. In column 6 are given the values, in sensation units, of the corresponding intervals on the sensation scale, determined by use of the scale-reading curve.

The values in column 6 should be equal if the theoretical requirements of a uniformly grade sensation scale are fulfilled by the samples used. The amount of departure from uniformity in these values indicates the extent of failure in the fulfilment of the ideal conditions. The uniformity is quite good considering the practical difficulties encountered in the preparation of color standards.

Many more data are needed for the establishment of the hue sensibility curve of the average normal eye, observations on a larger number of different individuals being required.

TABLE I.

1 No.	2 Name	3 Hue	4 Purity	5 $d\lambda$	6 ds
1	Spectrum Red	633	55	..	..
2		616	31	17	5.0
3		610	34	6	3.0
4		605	34	5	2.0
5		...	..	..	2.5
6	Orange Chrome	597	40	8	2.5
7		595	34	2	1.5
8		593	26	2	1.5
9		589	23	4	3.0
10		586	31	3	3.0
11		582	34	4	3.0
12	Lemon Yellow	579	29	3	3.0
13		577	34	2	2.0
14		574	39	3	2.0
15		569	42	5	3.0
16		566	42	3	2.0
17		548	47	18	8.0
18	Emerald Green	521	63	17	9.0
19		518	66	3	2.0
20		510	63	8	3.5
21		495	55	15	10.0
22		490	54	5	5.5
23		486	51	4	3.0
24		484	73	2	1.5

TABLE I.—*Continued.*

1 No.	2 Name	3 Hue	4 Purity	5 dA	6 ds
25	Spectrum Blue	479	70	5	2.5
26		476	57	3	2.0
27		470	62	6	3.0
28		460	62	10	4.0
29		445	58	15	8.0
30	Spectrum Violet	425	60	20	10.0
					3.8
		Purples.			
31		570	22	..	..
32		559	15	11	6
33		555	13	4	2
34		538	16	17	5
35		534	11	6	2
36		512	9.4	22	8

Colors Applied to Oil and Gas Storage Tanks. ANON. (*Scientific American*, vol. cxvi, No. 6, February 10, 1917.)—In considering the effects of the different types of rays of which light is composed, the calorific or heat-producing rays are conducted by painted or finished objects in a widely varying degree, according to a paper by Henry A. Gardner, presented before the annual meeting of the Pennsylvania State Association of Master Painters and Decorators at Philadelphia. This fact, it is stated, should be studied by the contracting painter who is called upon to paint the enormous area presented by metal oil tanks. Such tanks may contain light distillates which, upon becoming warm, produce highly expansible vapors. When black or dark colored paints have been used, rapid absorption takes place, and considerable losses by evaporation are apt to occur. White or light colored paint should therefore be used for the finishing coat on oil storage tanks. Paints presenting a high gloss are, moreover, less absorptive of thermal rays than those presenting a duller surface.

The experiment was made of exposing a number of small tanks containing benzine, painted in various colors with a gloss finish, to the rays of a carbon arc for a period of 15 minutes. The rise in temperature of the benzine in degrees Fahrenheit was, for black paint, 54° F.; for light gray, 26.3°; for white paint, 22.5°; for aluminum paint, 20.5°; and for tin plate, 19.8°. Although plain tin, on account of its smooth, bright surface, gave the best results, it does not constitute a practical finish, as iron coated with tin corrodes unless protected with paint. Aluminum paint gave very good results, but it is not nearly so serviceable as lead and zinc linseed oil paint.

NOTES FROM RESEARCH DIVISION, ELECTRICAL ENGINEERING DEPARTMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

A RESEARCH on "Skin-effect Resistance Measurements of Conductors at Radio-frequencies up to 100,000 Cycles per Second," by A. E. Kennelly and H. A. Affel, has recently been printed in the *Proceedings of the Institute of Radio Engineers*, and has been issued by the Electrical Engineering Department of the Massachusetts Institute of Technology as its Bulletin No. 13.[1] This research is a continuation and extension of preceding M. I. T. researches on skin effect already published.

The research deals with straight loops of copper conductor, the two sides of the loop being parallel, one being the outgoing and the other the return conductor. The source of alternating currents was an Alexanderson high-frequency alternator. The testing current in the loops of conductor was ordinarily 2 or 3 amperes. The testing frequencies ranged from 5000 to 100,000 cycles per second. The conductors included simple round copper wires, copper stranded cords, and copper strips. Two concordant methods of testing were employed. The preferred method involved a particular type of inductive bridge, with the parts fastened on the testing table. The observer had to maintain a constant position at this table during the tests; but, with this precaution taken, metallic shields or enclosures for the testing apparatus were not found requisite. The details of the apparatus are recorded in the paper.

It was found that the skin-effect resistance ratio—*i.e.*, the ratio of a.-c. to d.-c. effective resistance of round copper wires—conformed to the standard Heaviside-Kelvin Bessel-function formulas within the limits of experimental error. There seems to be no reason why this conformity should not exist up to 100,000 cycles per second; but at least there is satisfaction in arriving at the experimental check.

The resistance ratio of a strand of seven bare copper wires,

* Communicated by the Director.

[1] Copies of this bulletin may be had by addressing The Bursar, Massachusetts Institute of Technology, Cambridge, Mass.

all in contact, but without twist, was found to be the same as that of the equisectional solid round copper wire, within the limits of experimental observation. This and similar observations with straight stranded wires at lower frequencies lead to the inference that the subdivision of a round wire into a round cable of uninsulated parallel contacting strands does not alter the skin-effect resistance ratio.

As the parallel strands of the subdivided wire were separated, as by insulating material (enamel, cotton, etc.), the resistance ratio rapidly diminished.

The simple spiralling of the strands of a cord, in one and the same direction, introduced a spirality effect and increased the resistance ratio.

The resistance ratio of a copper strip was found to be usually, but not invariably, less than that of an equisectional round copper wire. The skin effect in strips is greatly increased above that which might be inferred from the thickness of the strip, owing to the existence of "edge effect"; *i.e.*, the tendency of the alternating-current density to increase toward the edges, and to denude the central portions of the strip. The edge effect is a phenomenon closely akin to the ordinary skin effect. In both, the current density increases from the axis of the conductor towards the outlying regions of the cross-section.

Slitting a strip with slits parallel to its length did not appreciably alter the resistance ratio.

Increasing the width of a strip conductor increases the edge effect consequently when rolling a round wire into a flat strip, the resistance ratio is ordinarily first reduced as the strip is made thinner, owing to diminishing skin effect; but, after a certain point, the increasing width of the strip increases the edge effect faster than the skin effect is reduced; so that there is a certain most favorable strip thickness in each case for alternating currents of a given frequency.

Placing the going and returning strips in close juxtaposition, with only a thin strip of paper between their opposed surfaces, reduced the edge effect.

Rolling up the edges of a flat copper strip to form a copper tube with a narrow slit destroyed the edge effect and reduced the resistance ratio to a minimum, dependent only on the strip thickness. It would seem that there is no limit to the reduction

of skin-effect extra resistance obtained in this way by using hollow tubular conductors of sufficient wall thickness, provided that they can be mechanically supported. Conductors with braided strands of fine wire, woven stocking-fashion over a non-conducting flexible core, were found to have very small skin effect.

Measurements are now being conducted on single-layer coils or solenoids to determine their resistance ratios at radio frequencies.

The mathematical laws of the edge effect in copper strips of ordinary widths have not yet been worked out, except in the particular case of opposed flat parallel strips separated by insulating layer of relatively small thickness. For this case a simple formula is given, following the results originally published by Lord Rayleigh.

Initiation of Explosions. W. ARTHUR. (*Proceedings of the Engineers' Club of Philadelphia*, vol. xxxiv-3, No. 148, p. 135, March, 1917.)—Until quite recent times, black powders or kindred mixtures were the only explosives in use. The energy they contained was liberated by the burning of the mixture, only the minutest flame being required to start the ignition, as the various components were extremely finely divided, and only a small amount of heat was sufficient to raise them to the ignition point. The beginning of what may be termed internal ignition in contradistinction to the previous method, which may be styled external ignition, followed the discovery of mercury fulminate by Howard in 1799. Its ability to fire gunpowder gave rise about the year 1815 to the development of the percussion cap.

The percussion cap may be briefly described as a small metal capsule containing mercury fulminate or mercury fulminate mixture, or other mixture with similar properties. The cap was used by placing it over the end of a small tube leading to the powder chamber. When struck a sharp blow, the mixture detonated, giving rise to considerable heat and igniting the powder. The significance of this invention was as great as the discovery of gun-cotton or smokeless powder, the use of fixed ammunition in modern firearms having been made possible by a dependable primer. The length and heat of the primer flame will determine very largely the character of explosion of the charge. If the flame be short and the temperature not very high, only a portion of the powder may be burned before the projectile leaves the muzzle of the gun. On the other hand, if the primer flame be long and the temperature high, all of the powder may be fired. Mercury fulminate has for many years held its place as a detonating substance superior to all others. In recent years, however, its place has been threatened by other compounds which bid

fair to displace it. One of the most promising of these is lead azide, a salt of hydronitric acid.

The chief characteristic of mercury fulminate which makes it valuable as a detonating agent is the ease with which it can be exploded by simple and ordinary means, and the characteristic mode of pressure development which brings about the explosive decomposition of the charge. A large number of chemicals are violent explosives and many exceed mercury fulminate in explosive power, but are less suitable as detonators, or are not suitable at all. Some are too sensitive to shock or friction, others too unsensitive; mercury fulminate occupies a middle position. Many investigators have attempted to account for the initiating effect of detonating compounds, but so far no fully satisfactory theory of their action has been formulated.

Poor Commutation Traced to Frame Vibration. ANON. (*Electrical World*, vol. 69, No. 8, p. 372, February 24, 1917.)—There are so many well-known possible causes of unsatisfactory commutation that when a commutation trouble occurs with a machine of admittedly good design a trouble seeker is likely to direct his attention to eliminating the most common causes before looking for the more uncommon ones. In one particular instance the generator of a motor generator set, that consisted of a continuous current generator driven by an induction motor mounted on a rather long base, commutated rather badly. The sparking was not sufficiently bad to prevent operating the set, but so long as it continued the commutator could never take a polish.

The operator had checked the speed, voltage, load, polarities, air-gap, field drops, brush sets, brush tensions, brush alignments, brush shift, and also the switchboard instruments, and everything appeared to be perfectly regular. The commutator mica appeared to be flush with the bars, but, as it is sometimes difficult to tell with certainty whether or not mica is a little high, it was decided to slightly undercut it as an experiment. At this time a turbine construction man happened along (turbine men are usually very keen for any condition that is likely to produce vibrations), who noticed that oil was breathing out between the bearing cap and pedestal of the middle bearing. This struck him at once as a case of faulty alignment, with the possibilities and causes of which he was thoroughly familiar.

Two iron wedges were made and driven under the centre of the base on opposite sides of the machine. A relief was immediately noticeable, and the vibration that before had been evident only to the most skilful observer was missed at once. The sound emitted by the machine, especially at the brushes, became entirely different, and all sparking ceased. Investigation disclosed that the base of the machine as originally set was virtually resting on its four corners, so far as the distributing of the weight on the foundation was concerned, and the long span of the base had sagged.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, March 21, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 21, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 45.

The paper of the evening, entitled "Chemistry and American Industry," was presented by Allerton S. Cushman, Esq., A.M., Ph.D., Director, the Institute of Industrial Research, Washington, D. C. The speaker discussed the subject particularly from the standpoint of the products which were obtained mainly from foreign countries prior to the present war. Considerable attention was given to the production of potash and its various compounds, with respect to which there has practically been a famine in this country since the beginning of the war. Fixed nitrogen and the various purposes for which this product is used also formed an important part of the paper. The speaker particularly called attention to those chemicals and chemical compounds essential to the successful prosecution of war, and spoke frankly of the government's needs in the present crisis.

A series of moving-picture films showing the fixation of nitrogen as carried on at the plant of the Cyanamid Company at Niagara Falls, N. Y., were shown by the courtesy of the Bureau of Economics, of Washington.

The paper was discussed by Mr. A. W. Gibbs, Dr. H. F. Keller, and others.

Mr. Gibbs offered the following resolution, which was unanimously carried:

"Resolved, That in thanking Dr. Cushman for his instructive paper we wish especially to thank him for the frankness with which he has stated our unprepared condition and the reasons for it."

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, March 7, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 7, 1917.

MR. W. C. WETHERILL *in the Chair.*

The following report was presented for first reading:

No. 2688.—Chainomatic Balance.

The following report was presented for final action:

No. 2681.—International Money Machine. Recommended that the

Edward Longstreth Medal of Merit be awarded to the International Money Machine Company for the development of this device, and also recommended that the City of Philadelphia award the John Scott Legacy Medal and Premium to Thomas Bilyeu for his inventions embodied in it.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 1, 1917, at 8 P.M.

Mr. J. A. P. Crisfield occupied the chair.

Mr. Crisfield introduced Henry Souther, Esq., Consulting Engineer, Aviation Section, U. S. Army, War Department, Washington, D. C., who delivered a lecture, entitled "Development and Progress in Aviation Motors."

With the help of lantern slides, Mr. Souther briefly reviewed the aëroplane motors that were of real use early in the art, and the progress made both in the United States and Europe (so far as can be obtained from war service experience); the recent evolution in the United States Army, and the vision for the future were also discussed. The lecture did not deal with the thermal efficiency of motors or other technical details except to show the progress in horsepowers considered necessary at different periods and for different purposes. Reference was also made to materials used in motors.

After an interesting discussion, a rising vote of thanks was extended to the speaker.

Adjourned.

T. R. PARRISH,
Acting Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday, March 8, 1917, at 8 P.M.

Mr. Charles E. Bonine and Mr. H. P. Liversidge presided jointly.

C. E. Skinner, M.E., Engineer of Research Division, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., delivered a lecture, entitled "Dielectric Losses in Insulating Materials." Mr. Skinner gave a brief *résumé* of past work done along this line, followed by a description of apparatus and methods used in a fairly elaborate study of the subject at high voltages. Results of tests on various kinds of materials under different conditions were given. The reasons for this study were outlined, showing the importance of this method of valuating insulating materials and structures. Brief reference was made to the research facilities and equipment of the Westinghouse Electric and Manufacturing Company, particularly the extensive new building and equipment which is just being put into operation.

After an interesting discussion by Mr. Charles E. Bonine, Dr. Harold Pender, Prof. Clarence E. Clewell, and others, a rising vote of thanks was extended to Mr. Skinner, and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

Mechanical and Engineering Section.—A joint meeting of the Section and the American Society of Mechanical Engineers was held in the Hall of the Institute on Thursday, March 15, 1917, at 8 o'clock P.M.

Mr. George R. Henderson, president of the Section, and Mr. Joseph A. Steinmetz presided jointly.

Mr. Henderson introduced Jerome C. Hunsaker, Eng.D., Assistant Naval Constructor, Navy Department, Washington, D. C., who delivered a lecture, entitled "Design, Construction, and Equipment of a Modern Military Aëroplane." Dr. Hunsaker discussed the principles of aëroplane design and their application in modern naval and military aëroplanes. The lecture was fully illustrated with lantern slides and moving pictures.

After an interesting discussion, a vote of thanks was extended to the speaker.

Adjourned.

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, March 14, 1917.)

RESIDENT.

MR. H. C. BOOZ, Assistant Chief Engineer, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

MR. RONALD G. COOLBAUGH, Mechanical Engineer, Joseph Campbell Company, Camden, N. J.

MR. WILLIAM J. FITZMAURICE, JR., 121 South Alden Street, Philadelphia, Pa.

MR. F. G. GRIMSHAW, Assistant Engineer of Electric Equipment, Pennsylvania Railroad Company, West Philadelphia, Pa.

MR. THOMAS W. HULME, Real Estate Agent, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

MR. JOSEPH KOHN, Superintendent, International Tooth Company, and for mail, 2204 Natrona Street, Philadelphia, Pa.

MR. ELISHA LEE, Assistant General Manager, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

MR. ARTHUR W. LOWE, Public School Teacher, 1238 Harrison Street, Philadelphia, Pa.

MR. FRANK D. LYONS, 6769 Ridge Avenue, Roxborough, Philadelphia, Pa.

MR. THOMAS S. MARTIN, 3RD, Civil Engineer, 770 North Forty-first Street, Philadelphia, Pa.

MR. FRANCIS F. MILNE, JR., 1714 Spruce Street, Philadelphia, Pa.

MR. W. HEYWARD MYERS, Vice-President, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

MR. THEODORE W. REATH, Lawyer, 1201 Commercial Trust Building, Philadelphia, Pa.

MR. GROVER C. SESSLER, Construction Engineer, Midvale Steel Company, Nicetown, Philadelphia, Pa.

MR. W. A. SHMIDHEISER, Mechanical Engineer, 6017 Pine Street, Philadelphia, Pa.

MR. W. HINCKLE SMITH, Banker, 201 Liberty Building, Philadelphia, Pa.

DR. WALTER T. TAGGART, Department of Chemistry, University of Pennsylvania, Philadelphia, Pa.

MR. BENJAMIN CHEW TILGHMAN, 7913 Crefeldt Street, St. Martins, Philadelphia, Pa.

MR. M. TRUMP, Civil Engineer, Special Assistant to General Manager, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

MR. SAMUEL T. WAGNER, Civil Engineer, Chief Engineer, Philadelphia and Reading Railway Company, Reading Terminal, Philadelphia, Pa.

NON-RESIDENT.

MR. J. R. ALEXANDER, General Road Foreman of Engines, Pennsylvania Railroad Company, Altoona, Pa.

MR. C. D. BARRETT, Master Mechanic, Pennsylvania Railroad Company, Sunbury, Pa.

PROF. G. H. BROWN, Director, Department of Ceramics, Rutgers College, New Brunswick, N. J.

MR. S. H. CHURCH, President, The Carnegie Institute, Pittsburgh, Pa.

MR. J. L. CUNNINGHAM, Master Mechanic, Pennsylvania Railroad Company, Harrisburg, Pa.

MR. R. L. ETTENGER, Consulting Mechanical Engineer, Southern Railway Company, 1300 Pennsylvania Avenue, Washington, D. C.

MR. W. C. A. HENRY, Superintendent Motive Power, Pennsylvania Lines West of Pittsburgh, Columbus, Ohio.

MR. GEORGE B. KOCH, General Foreman, South Altoona Foundries, Pennsylvania Railroad Company, Altoona, Pa.

MR. J. KRUTTSCHNITT, Civil Engineer, Railroad Executive, Southern Pacific Company, 165 Broadway, New York City, N. Y.

MR. T. A. LAWES, Mechanical Engineer, The New York, Chicago and St. Louis Railroad Company, Cleveland, Ohio.

MR. C. L. MCILVAINE, Master Mechanic, New York, Philadelphia and Norfolk Railroad Company, Cape Charles, Va.

MR. D. R. MACBAIN, Superintendent Motive Power, New York Central Railroad Company, Cleveland, Ohio.

MR. H. H. MAXFIELD, Superintendent Motive Power, Western Pennsylvania Division, Pennsylvania Railroad Company, Pittsburgh, Pa.

MR. J. MILLIKEN, Superintendent Motive Power, Philadelphia, Baltimore and Washington Railroad Company, Wilmington, Del.

MR. ALLEN E. NICHOLS, Civil Engineer, 5331 Woodlawn Avenue, Chicago, Ill.

MR. J. L. O'DONNELL, General Superintendent, Pennsylvania Railroad Company, Pittsburgh, Pa.

MR. F. N. PEASE, Chief Chemist, Pennsylvania Railroad Company, Altoona, Pa.

MR. G. L. PECK, Vice-President, Pennsylvania Lines West of Pittsburgh, 903 Pennsylvania Station, Pittsburgh, Pa.

MR. C. H. QUINN, Chief Electrical Engineer, Norfolk and Western Railway Company, Roanoke, Va.

MR. ELLIS B. RIDGWAY, Manufacturer, Coatesville, Pa.

MR. A. T. SMITH, The R. U. V. Company, Inc., 50 Broad Street, New York City, N. Y.

MR. EDWARD B. TAYLOR, Vice-President, Pennsylvania Lines West of Pittsburgh, 901 Pennsylvania Station, Pittsburgh, Pa.

MR. E. T. WHITER, Assistant General Manager, Pennsylvania Lines West of Pittsburgh, Pennsylvania Station, Pittsburgh, Pa.

MR. G. H. WOODROFFE, Mechanical and Metallurgical Engineer, Parkesburg Iron Company, Parkesburg, Chester County, Pa.

ASSOCIATE.

MR. WILLIAM J. BURGESS, 940 South Fifty-fifth Street, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. JOHN H. BARR, 374 Broadway, New York City, N. Y.

DR. FRANK K. CAMERON, care of American Smelting and Refining Company, Salt Lake City, Utah.

MR. JOHN GAREY, care of American Dyewood Company, Howell Street, Chester, Pa.

MR. CLARENCE A. HALL, Pelham Court, Germantown, Philadelphia, Pa.

MR. PENROSE R. HOOPES, 41 Hough Avenue, Bridgeport, Conn.

MR. D. W. LUM, P. O. Box 1808, Washington, D. C.

MR. JULIAN S. SIMSOHN, Hotel Majestic, Broad Street and Girard Avenue, Philadelphia, Pa.

MR. L. H. THULLEN, 30 Post Avenue, New York City, N. Y.

MR. JOHN C. TRAUTWINE, 3RD, 3943 Locust Street, Philadelphia, Pa.

NECROLOGY.

Mr. E. Eldridge Pennock was born July 9, 1857, and died on March 4, 1917. He was educated in private schools. Early in life he entered the employ of Francis H. H. Brook, a prominent grain merchant. He afterward formed a partnership with his employer, the firm being known as Brook & Pennock. Upon the death of Mr. Brook, Mr. Pennock continued the business under the name of Pennock & Company.

He was a member of many social organizations and clubs. Mr. Pennock became a member of The Franklin Institute on April 9, 1913.

Mr. John W. Steacy was born at Strasburg, Lancaster County, Pa., on June 9, 1833, and died at York, Pa., March 2, 1917. He was educated in the public schools and at Strasburg Academy.

In the first thirty years of his active life he was connected with a number of business enterprises, including iron and oil companies.

In 1878 Mr. Steacy became manager of the York Rolling Mill. This was reorganized in 1886, and became a joint stock company. In 1899 a consolidation of the more important rolling mills and furnaces took place, and Mr. Steacy became general manager of the new corporation.

In 1903 he withdrew from the concern and devoted his entire attention to the construction of suburban trolley lines around the city of York, Pa.

He was prominently identified with the civic, business, and charitable interests of the city of York.

Mr. Steacy became a member of The Franklin Institute on May 7, 1903.

LIBRARY NOTES.

PURCHASES.

AKINOFF, N. W.—Elementary Course in Lagrange's Equations, and their Applications to Solution of Problems of Dynamics. 1917.

American Society for Testing Materials.—Proceedings, vol. 19, pts. 1–2. 1916.

DOUBLEDAY, A. W.—Photomicrographs of Crystallizable Chemical Salts. 1916.

FLEMING, J. A.—Principles of Electric Wave Telegraphy and Telephony. 1916.

GREENE, A. M.—Elements of Refrigeration. 1916.

HIGGINS, S. H.—Dyeing in Germany and America, with Notes on Colour Production. 1916.

Industrial Arts Index, vol. 4. 1916.

LEGROS, L. A., and GRANT, J. C.—Typographical Printing Surfaces. 1916.

OSWALD, J. C.—Benjamin Franklin, Printer. 1917.

PAGE, V. W.—Automobile Starting, Lighting, and Ignition. 1916.

PAGE, V. W.—The Model T Ford Car. 1917.

PIDDUCK, F. B.—Treatise on Electricity. 1916.

Readers' Guide to Periodicals.—Annual, No. 16. 1916.

Readers' Guide to Periodical Literature.—Supplement, 1907–1915.

SHEPARDSON, G. D.—Telephone Apparatus: Introduction to the Development and Theory. 1917.

GIFTS.

Atlantic Deeper Waterways Association, Report of the Proceedings of the Ninth Annual Convention, 1916. Philadelphia, 1917. (From the Association.)

American Industrial Commission to France, Report, 1916. New York, 1917. (From the American Manufacturers' Export Association.)

American Institute of Electrical Engineers Year Book, 1917. New York, 1917. (From the Institute.)

American Railway Master Mechanics' Association, Report of the Proceedings of the Forty-ninth Annual Convention, 1916. Chicago, 1916. (From the Association.)

American Society of Civil Engineers, Transactions, vol. lxxx, December, 1916. New York, 1916. (From the Society.)

Boston Transit Commission Twenty-second Annual Report, June 30, 1916. Boston, 1916. (From the Commission.)

Buffalo, Rochester and Pittsburgh Railway Company, Thirty-second Report, 1916. New York, 1916. (From the Company.)

Burke and James Inc., Catalogue No. 14, Cameras, Photographic Supplies, and Apparatus. Chicago, no date. (From the Company.)

Canada Department of Mines Geological Survey: Memoir 89, Wood Mountain-Willowbunch Coal Area, Saskatchewan: Memoir 92, Part of the District of Lake St. John, Quebec. Ottawa, 1916. (From the Department.)

Canada Department of Mines, Mines Branch: Researches on Cobalt, Part IV, Cobalt Alloys with Non-Corrosive Properties, by Herbert T. Kalmus and K. B. Blake; Feldspar in Canada, by Hugh S. deSchmid. Ottawa, 1916. (From the Department.)

Carnegie Institution of Washington, Year Book No. 15. Washington, 1916. (From the Institution.)

Carnegie Steel Company, Pocket Companion for Engineers, Architects, and Builders, 19th edition; and Standard Specifications, 6th edition. Pittsburgh, 1917. (From the Company.)

Case School of Applied Science, Catalogue, 1916–'17. Cleveland, 1916. (From the School.)

Clark University, Register and Twenty-ninth Official Announcement. Worcester, Mass., 1917. (From the University.)

Cleveland Automatic Machine Company, Catalogue Descriptive of Machine Tools; and Eighteen Articles, by J. P. Brophy, General Manager. Cleveland, 1915. (From the Company.)

Consolidated Press and Tool Company, Catalogue No. 10. Hastings, Michigan, 1914. (From the Company.)

Hall of Records Power Plant, Report and Discussion of Physical Test and Costs of Operation and Maintenance. New York, 1916. (From the New York Municipal Reference Library.)

Illinois Insurance Superintendent, Addresses and Papers on Insurance. Springfield, 1917. (From the Superintendent.)

Iowa Engineering Society, Proceedings of the Third, Tenth, Eleventh, Twelfth, Thirteenth, Fourteenth, Fifteenth, Sixteenth, Nineteenth, Twenty-first, Twenty-second, Twenty-third, Twenty-fourth, Twenty-fifth, and Twenty-sixth Annual Meetings. Iowa City, 1890–1914. (From the Society.)

Lake Mohonk Conference on the Indian and Other Dependent Peoples, Report of the Thirty-fourth Annual Conference, 1916. Mohonk Lake, 1916. (From the Conference.)

Master Car Builders' Association, Report of the Proceedings of the Fiftieth Annual Convention, 1916, parts 1 and 2. Chicago, 1916. (From the Association.)

Museu Nacional do Rio de Janeiro, Archivos, vol. xvii. Rio de Janeiro, 1915. (From the Museum.)

National Association of Cotton Manufacturers, Transactions, No. 101. Boston, 1917. (From the Association.)

Nela Research Laboratory, Abstract-Bulletin, January, 1917. Nela Park, Cleveland, 1917. (From the Laboratory.)

New York Electric Railway Association, Thirty-first, Thirty-third, and Thirty-fourth Annual Reports. Albany, 1913–1916. (From the Association.)

New York Public Service Commission, Second District, Ninth Annual Report, 1915, vol. ii. Albany, 1916. (From the Commission.)

New Zealand Department of Mines, Mines Statements, 1915. Wellington, 1916. (From the Department.)

Niles-Bement-Pond Company, Condensed Catalogue of Machine Tools. New York, 1913. (From the Company.)

Ontario Bureau of Industries, Annual Report, 1912, parts i and ii. Toronto, 1913. (From the Department of Agriculture.)

Penberthy Injector Company, Catalogue No. 28. Detroit, no date. (From the Company.)

Pennsylvania Commissioner of Banking, Twenty-first Annual Report, 1915. Part II, Building and Loan Associations. Harrisburg, 1916. (From the State Librarian.)

Pennsylvania Department of Agriculture, Twenty-first Annual Report, 1915. Harrisburg, 1916. (From the State Librarian.)

Pennsylvania Department of Mines, Report, 1915. Part i, Anthracite. Harrisburg, 1916. (From the State Librarian.)

Pennsylvania Railroad, Record of Transportation Lines for the Year ending December 31, 1916. Philadelphia, 1917. (From the Company.)

Polytechnic Institute, Catalogue of the College of Engineering, 1917–'18. Brooklyn, 1917. (From the Institute.)

Princeton University, Catalogue, 1916–'17. Princeton, 1916. (From the University.)

Rice Institute, Book of the Opening, 1912, vols. i, ii, and iii. Houston, Texas, no date. (From the Institute.)

Rose Polytechnic Institute, Thirty-fifth Annual Catalogue. Terre Haute, Ind., 1917. (From the Institute.)

Smith College, Catalogue, 1916–'17. Northampton, Mass., 1916. (From the College.)

Staffordshire Iron and Steel Institute, Proceedings, vol. xxxi, Session 1915–'16. Stourbridge, 1917. (From the Institute.)

St. Louis University, Catalogue, 1917. St. Louis, Mo., 1917. (From the University.)

Tennessee Railroad Commission, Report, 1915–'16. Nashville, 1916. (From the Commission.)

University of Michigan, Astronomical Observatory, Publications, vol. ii. Ann Arbor, 1916. (From the University.)

University of Rochester, Annual Catalogue, 1916–'17. Rochester, 1917. (From the University.)

University of South Dakota, Thirty-fourth Annual Catalogue, Vermillion, 1916. (From the University.)

U. S. Navy Department, Naval Militia Cruises, 1916; and Naval Militia Register, January 1, 1917. Washington, 1917. (From the Department.)

U. S. Reclamation Service, Fifteenth Annual Report, 1915–'16. Washington, 1916. (From the Service.)

Washington University, Sixtieth Annual Catalogue. St. Louis, Mo., 1916. (From the University.)

Western Electric Company, Electrical Supply Year Book. New York City, 1917. (From the Company.)

Western Reserve University, Catalogue, 1916–'17. Cleveland, 1917. (From the University.)

Wisconsin Academy of Sciences, Arts, and Letters, Transactions, vol. xviii, part ii 1916, with Index. Madison, 1916. (From the Academy.)

Yale University, General Catalogue, 1916–'17. New Haven, 1916. (From the University.)

BOOK NOTICES.

Bridge Engineering, by J. A. L. Waddell, C.E. In two volumes, 8vo., cloth, 2177 + lxxv pages, 560 illustrations, and 90 tables. John Wiley & Sons, Inc., New York, 1916. Price, $10.

Under a brief but appropriately comprehensive title, Dr. Waddell has made a most important and unique contribution to engineering literature. In judiciously arranged sequence, he has formulated a code of practice embodying all the information he has been able to accumulate concerning every branch of bridgework during a practice of forty years, and few have earned an equal right to speak with authority on the subject.

Covering the topics embraced in the elements of many types of bridges, coupled with a great wealth of data and discussion, the work is necessarily voluminous. Sixty pages are devoted to a table of contents and lists of figures, diagrams, and tables; 1893 to text; 224 to a glossary of bridge engineering terms, and 61 to an index. Primarily the work is addressed to the younger members of the profession, to whom it will undoubtedly prove a valuable guide in avoiding the many pitfalls that confront anyone whose judgment is not ripened by wide experience. Besides, the copious information of a general nature scattered throughout the work should make it useful to men whose duties are of an administrative nature who may not be engineers, as well as to executives who may require authoritative information.

It is fair to assume that many engineers will differ from Dr. Waddell or will be unwilling to follow him closely. To such there is at least much value in the suggestion and challenge of his forceful statements and discussions. Probably the most valuable assistance to the bridge engineer is the extensive collection of tables and cross-section diagrams, most of which are the accumulation of many years of varied professional practice. Of much interest are the discussion and diagrams showing the comparative weights and cost of bridges built of carbon steel and mixed nickel and carbon steel, and of these materials with a "purified" steel made in France, and with other alloy steels. Loads are elaborately discussed and amply illustrated with numerous diagrams. The loads from electric locomotives and the possibility of resulting unprecedentedly heavy concentrated loads have apparently been omitted.

Chapter XVIII, dealing with "Shop Work as Affecting Bridge Design," includes points suggested by two eminent engineers of bridge manufacturers, whereby economy is effected in manufacture and erection, and a discussion by the author. Chapter XLV, on "Expedients in Design and Construction," has numerous examples of the importance of the ingenuity and originality that may be exercised in handling many problems of design and construction. Chapter LXXVIII and LXXIX cover the "General Specifications of Design" and of "Manufacture and Erection," respectively, and are most complete. It may be noted, however, that they do not cover the special condition to be met when bridges are to be exported to foreign countries where facilities for transportation and erection may require special construction and design.

The final glossary of terms is extraordinarily complete, and contains those terms common among workmen and rarely found in books, which are unknown to the foreign engineer and not always known to the experienced engineer in this country.

Throughout the work frequent references are made to other leading authorities, and ample credit is given to engineers from whom he quotes, including those who differ from him. The work tells the life-story of an extensive, varied, and successful career; and, while it contains much matter for discussion and dispute, it is indeed a valuable contribution to the profession and a fitting climax to the active business life of the able author.

PERCY S. HILDRETH.

PRINCIPLES OF QUANTITATIVE ANALYSIS: An Introductory Course, by Walter C. Blasdale, Ph.D. New York, D. Van Nostrand Company, 1917. Second edition. 388 pages, 70 illustrations, contents, tables, and index. 12mo. Price, $2.50 net.

A second edition that follows the first in about two years needs no special encomiums from a reviewer, for it is evident that the work has been acceptable to those for whom it was intended. The book is written in full accord with the modern theories of physical chemistry, and illustrates vividly how useful these theories are in their practical application. The subject-matter is largely concerned with inorganic chemistry, but a few processes that are usually included in commercial organic analysis are given. The theory and practice of each procedure are carefully explained, and some problems are given in connection with each important section. It might be an advantage to indicate, in connection with each problem, the pages on which the data available for the solution thereof are to be found, but, as the book will be almost entirely used in association with competent instructors, this is possibly a minor matter. I am pleased to see that Dr. Blasdale has the courage and good judgment to write "thru" and "thruout," and regret that he does not see his way clear to drop the useless final "e" in the many chemical terms in which it occurs. Especially it is to be regretted that "glycerol" is termed "glycerine." Even that last text-book citadel of conservative orthography, the U. S. Pharmacopœia, has dropped the final "e" in this word.

The book is excellently printed, of convenient size and shape, on good paper, and well illustrated.

HENRY LEFFMANN.

PRACTICAL PHYSIOLOGICAL CHEMISTRY: A Book Designed for Use in Courses in Practical Physiological Chemistry in Schools of Medicine and of Science, by Philip B. Hawk, M.S., Ph.D., Professor of Physiological Chemistry and Toxicology in the Jefferson Medical College of Philadelphia. Fifth edition, revised and enlarged. 638 pages, illustrations, plates. 8vo. Philadelphia, P. Blakiston's Son & Company, 1916. Price, $3.

Five new chapters have been inserted in this edition. One chapter is devoted to the nucleoproteins and nucleic acids and their constituents, and to the enzymes which produce biochemical changes in these compounds. The

chapter on gastric analysis contains a discussion of hydrogen ion concentration and titratable acidity, the determination of hydrogen ion concentration by indicators, and the fractional method of gastric analysis, including the use of the stomach-tube of Rehfuss. The chapter on intestinal digestion is devoted exclusively to digestive processes brought about by enzymes which have their origin in the intestine. Among the subjects presented in the chapter on blood analysis, mention should be made of the following: New methods for the determination of the various nitrogenous constituents, sugar, acetone bodies, chlorides, lipins, the hydrogen ion concentration (by means of phenolsulphonephthalein); the description of the nephelometer and its use in blood analysis. In the chapter on metabolism, an elaborate series of experiments is given, involving the manipulation of either or both the urine and the fæces. In addition to the new chapters, just reviewed, additions to the text have been made throughout the volume, including the Van Slyke and the ninhydrin methods for the determination of amino nitrogen, the nephelometric estimation of milk proteins, the phenolsulphonephthalein renal function test, the determination of the hydrogen ion concentration of urine by indicators, micro methods for the nitrogenous constituents of the urine, the urease method for the determination of urea, and the colorimetric determination of phenols by means of phospho-tungstic and phospho-molybdic acids. In all the chapters the analytic methods have been rearranged in sections on principle, procedure, calculation, and interpretation. The laboratory procedure in the most important tests and methods is printed in blackface type for convenience of reference.

The demand for this book is shown by the fact that during one decade five editions have appeared, and one edition has been reprinted twice.

JOSEPH S. HEPBURN.

MICROBIOLOGY: A Text-Book of Microörganisms, General and Applied. Edited by Charles E. Marshall. Philadelphia, P. Blakiston's Son & Company, 1917. Second edition, revised and enlarged. 861 pages, contents and index. 12mo. Price, $3 net.

Twenty-five specialists, American and foreign, have assisted Professor Marshall in the preparation of this book, which is packed with a large amount of the most interesting and important information. The success of the first edition has shown the merit of the work. There is scarcely a department of science in which modern development has been of more practical value to the human race than that covered by this work. In consideration of topics it ranges from data concerning microörganisms in important industries, such as wine and vinegar manufacture, to the study of the diseases affecting insects. The latter subject is closely connected with the production of food, for many insects are destructive to food animals and food plants, and the destruction of such pests has been accomplished by cultivating the specially antagonistic microörganisms. An instance is the fungus that destroys the common house-fly. One of the most important instances of insect infection of a serious nature is the disease of the silkworm, which Pasteur investigated in 1869 and against which he introduced effective measures.

Although prepared as a text-book, the work is well adapted for perusal by the non-professional who desires to get information as to the multiplicity of enemies that man and his supporting animals have in the microscopic world. Not all minute organisms, however, are hostile, and the friendly ones are also given good notice.

The book is well printed on good paper and of convenient size.

HENRY LEFFMANN.

ANNUAIRE POUR L'AN 1917. Publie Par le Bureau des Longitudes. Paris, Gauthier-Villars & Company, 1917. 700 pages, illustrations, portraits, maps. 16mo. Price, two francs.

This well-known annual contains in the present issue the usual astronomical, meteorologic, and metrologic data, with three special essays of much interest: The Babylonian Calendar, by G. Bigourdan: The Advance of Legal Time during the Summer of 1916 (Daylight-saving), by J. Renaud, and The Valuation of the Meter in Terms of Wave-lengths of Light, by M. Hamy.

PUBLICATIONS RECEIVED.

Gas Chemist's Handbook, compiled by Technical Committee, Subcommittee on Chemical Tests, 1916—C. C. Tutwiler, chairman; A. F. Kunberger, editor. 354 pages, illustrations, 8vo. New York, American Gas Institute, no date. Price, $3.50.

Interior Wiring and Systems for Electric Light and Power Service: A manual of practice for electrical workers, contractors, architects, and schools, by Arthur L. Cook, head of Department of Applied Electricity, Pratt Institute. First edition. 416 pages, illustrations, diagrams, 16mo. New York, John Wiley and Sons, 1917. Price, $2.

Physical Laboratory Experiments for Engineering Students, by Samuel Sheldon, Ph.D., D.Sc., and Erich Hausmann, E.E., Sc.D. Part i, Mechanics, Sound, Heat and Light. 134 pages illustrations 12mo. New York, D. van Nostrand Company, 1917. Price, $1.25.

Canada Department of Mines, Mines Branch: Feldspar in Canada, by Hugh S. deSchmid, M.E. 125 pages, illustrations, plates, maps. Researches on Cobalt and Cobalt Alloys, conducted at Queens University, Kingston, Ontario, part iv, Cobalt Alloys with Non-corrosive Properties, by Herbert T. Kalmus, B.Sc., Ph.D., and K. B. Blake, B.Sc. 37 pages, illustrations plates, 8vo. Ottawa, Government Printing Bureau, 1916.

United States Bureau of Mines: Bulletin 128, Refining and Utilization of Georgia Kaolins, by Ira E. Sproat. 59 pages, illustrations, plates, 8vo. Bulletin 143, Abstracts of Current Decisions on Mines and Mining Reported from May to August, 1916, by J. W. Thompson. 71 pages, 8vo. Coal-mine Fatalities in the United States, 1916, compiled by Albert H. Fay. 42 pages, 8vo. Technical paper 165, Quarry Accidents in the United States during the Calendar Year 1915, compiled by Albert H. Fay. 77 pages, plate, 8vo. Technical paper 168, Metal-mine Accidents in the United States during the Calendar Year 1915, compiled by Albert H. Fay. 114 pages, 8vo. Washington, Government Printing Office, 1916–'17.

Concrete Highway Magazine, devoted to concrete roads, streets, and alleys. Published by the Portland Cement Association. Vol. i, No. 1, January, 1917. Chicago, Association, 1917. 22 pages, illustrations 8vo.

U. S. Department of Agriculture, Office of the Secretary: Circular No. 72, Width of Wagon Tires Recommended for Loads of Varying Magnitudes on Earth and Gravel Roads, prepared by E. B. McCormick, Chief, Division of Rural Engineering. 6 pages, diagrams, 8vo. Washington, Government Printing Office, 1917.

North Carolina Geological and Economic Survey: Press Bulletin No. 156, The Ash in North Carolina. 8 pages, 8vo. Some Facts and Figures about North Carolina and her Natural Resources. Second edition. 51 pages, 24mo. Raleigh, State Printers, 1917.

Temperature Measurements in Bessemer and Open-hearth Practice, by George K. Burgess, Sc.D. 13 pages, 8vo. Preprint from Transactions American Institute of Mining Engineers, February, 1917.

India's Appeal to Canada, or an Account of Hindu Immigration to the Dominion, by a Hindu-Canadian. 16 pages, 8vo. Toronto, Canada India League, 1916. Price, 10 cents.

Colorimetric Test for Organic Impurities in Sands, by Duff A. Abrams, professor in charge of laboratory, and Oscar E. Harder, chemist. Circular No. 1, Structural Materials, Research Laboratory, Coöperation of Portland Cement Association and Lewis Institute. 7 pages, 8vo. Chicago, Lewis Institute, 1917.

Your Streets: Concrete for Permanence. 34 pages, illustrations, 8vo. Chicago, Portland Cement Association, 1917.

Insulation of Transmission Lines Near Cement Mills. ANON. (*Electrical World*, vol. 69, No. 8, p. 372, February 24, 1917.)—In a number of instances successful service has been maintained on lines serving or passing cement mills by the simple expedient of extra insulation. It has been recommended in the case of 44,000-volt lines that twice the standard number of disks should be used per string, and periodically the line should be killed and the insulator disks carefully wiped with a cloth saturated with transil oil. For 60,000-volt lines, in addition to doubling the normal number of disks, duplicate lines have sometimes been constructed in the vicinity of a mill, so that the service need not be interrupted when the insulators are being cleaned, as power can be supplied over one branch while the other branch is dead. These methods of using double insulation to safeguard service have proved equally successful in regions where salt deposit is heavy.

CURRENT TOPICS.

German and Austrian Heavy Field Artillery. F. T. HINES. (*Journal of the United States Artillery*, vol. 47, No. 1, p. 70, January-February, 1917.)—The German and Austrian military authorities early foresaw the controlling effect of heavy mobile field artillery in future warfare, and they prepared accordingly. Their early successes and their present unbroken front are largely due to their possession of numerous heavy howitzers, of which the Allies, for the first year at least, possessed practically none. Long before the war, and at least in 1908, funds (some $2,000,000) were obtained by the German military authorities for a competitive test of various types of heavy ordnance on auto-trucks or of their transportation by tractors. Exhaustive tests were made in that year and also during 1911, which resulted in the formation of auto-truck companies or batteries of heavy field and siege artillery. It is now known that the German forces had 42-cm. (16.5-inch) mortars, manufactured, no doubt by the Krupps, some time before the war, and considerable confusion has occurred between this German 42-cm. mortar and the Austrian 305-mm., commonly referred to as the "Skoda."

The Skoda howitzer was developed by the Austrian authorities before the war broke out, and it is to them that the reduction of the Belgian forts and those of Przemysl is largely due. They have proved very accurate and their shells have terrific effect, both against fortifications and troops in the field. They fire a shell weighing 860 pounds with a muzzle velocity of 1115 foot-seconds, their maximum range being 14,000 yards. They are very mobile and can be mounted in 24 minutes and entirely dismounted and moved away in 40 minutes. They are transported in sections on tractors at a rate of 12 miles per hour. These tractors are drawn by a Skoda-Daimler car of 100 horsepower with four driving wheels, and at low speed can go up a 16 per cent. grade. From data available, it appears that the recoil of the Skoda mortar is taken up by oil cylinders, and is returned into battery by compressed air. The piece is set on a portable foundation when the ground is soft. When the foundation is used the piece can be traversed 60 degrees on each side of the median line; without the foundation, a slightly less angle of traverse is possible.

Data available would seem to indicate that the German forces have two very different types of 42-cm. mortars or howitzers: one transported by motor trucks, the other on railway cars. The latter type is more powerful than the former, and is placed on a concrete base, while the former is fired from its wheeled carriage. The first of these is a graceful and well-proportioned piece of ordnance, 5

metres in length, with a bore of exactly 42 cm. between lands. The shell weighs about 1800 pounds. The most effective range is about 10,200 yards, though the maximum range is much greater. The second type is permanently mounted on a specially designed railway truck from which it is fired. The piece is put in battery by chocking the platform on the track and on the ground by means of hydraulic jacks so as to take the weight completely off the trucks. It fires a projectile weighing about 1980 pounds with a bursting charge of 264 pounds of picric acid or trinitrate of toluene, and has a range of 15,300 yards.

Electricity from Wind Power. F. S. CULVER. (*Electrical World*, vol. 69, No. 8, p. 367, February 24, 1917.)—Generation of electricity by wind power is a problem that has been studied by numerous inventors for many years, yet very few of them have compiled data which can be used in the design of small rural lighting plants. Furthermore, most of the arrangements which have been tried out have been abandoned owing to their complexity, inefficiency, or cost. Believing that there would be a field for wind-power generators, however, if a simple and durable construction could be developed, the writer installed two experimental plants in Wisconsin and conducted extensive tests to determine the best method of utilizing the wind.

One of these plants was erected on a farm in northern Wisconsin. A rough estimate of the number of lamp-hours required showed that a battery of 26 cells having a normal discharge rate of three ampères for eight hours would be ample to provide lighting for several nights on one full charge. For charging the battery, a generator rated at three ampères and 65 volts was selected. From information obtained on wind velocity it was decided to erect an ordinary pumping form 12-foot windmill on a 50-foot steel tower. Regulating features of the windmill limited its maximum velocity to 75 revolutions per minute. To assure charging with winds of low velocity, a generator was selected having a normal speed of 900 revolutions per minute but having a pulley ratio which made it operate at 1800 with the maximum windmill speed of 75 revolutions per minute. Heavy charging current was prevented by a differential winding. An automatic cut-in connects the generator with the battery whenever the generator voltage is in excess of the battery voltage, and breaks the circuit just before the current reaches zero value or point of reversal. A waterproof generator was employed, being attached to the turn-table of the windmill below the axis and a little to one side, driven by a sprocket-wheel and standard automobile chain. Connections were made by means of collecting brushes attached to the stationary framework of the windmill.

Although mounting the generator at the top of the windmill affords a very efficient drive, the generator is inaccessible. It was therefore decided to erect another experimental plant in which the

generator would be placed in a building in the base of the tower. The second plant was erected in southern Wisconsin and consisted of a 12-foot wheel mounted on a 50-foot tower driving a six-ampère, 35-volt generator at 900 revolutions. The battery used with this equipment was rated at six ampères and consisted of 14 cells. A standard windmill with a vertical shaft terminating in a footjack was employed, and bevel gears were used to transmit power to a horizontal shaft extending into the building. The generator was driven from this shaft by an ordinary pulley and belt.

Both of these plants proved of ample capacity for the work required and of equal efficiency and cost, but the second plant has the advantage of greater simplicity and suggests the possibility of using this system in connection with any power windmill that may be already in use. Some of these plants have been in operation for six years, furnishing illumination every night, and there seems to be no question of their durability.

Spray Irrigation. M. B. WILLIAMS. (*U. S. Dept. of Agriculture, Bulletin 495,* February 14, 1917.)—Within the past two years spray irrigation, one of the most recent methods of applying water to crops to be adopted in the United States, has come into use over a wide area, especially in the Atlantic coast states. Among other advantages of spray irrigation, it may be satisfactorily used on both light and heavy soils, and on hillsides as well as on level ground. By this system water may be applied very lightly to delicate crops and plant seedlings, or, when weather conditions require, as a slight supplemental supply of moisture, and, on the other hand, it may be applied heavily during protracted dry periods. Where economic conditions are favorable to the adoption of spray irrigation, the most important question then becomes the possibility of securing an adequate water supply. Since the system is in use chiefly in the humid or semi-humid regions, practically all installations are made by individuals and do not involve the development and transportation of distant supplies, as is common for community irrigation in the arid regions. The sources of water supply for spray systems may be streams, springs, stored run-off, sumps for catching drainage water, and wells. In some sections of the East the storage of water falling on the roof of a building during the summer months is sufficient to irrigate a garden which is three times the area of the building. The reservoir in this case would need to hold about two months' rainfall, or the equivalent of six inches, falling on the roof.

Three types of spray irrigation construction have been employed more or less widely for field irrigation. The hose and movable nozzle, or movable lines, fed from an underground pipe system and hydrant, was one of the earliest systems to be developed and is still in rather extensive use for the irrigation of cold-frame and hot-bed crops, garden setting and seed beds, etc. Though the first cost of such a system is lower than that of the other types, it is the least

efficient. Stationary nozzles on vertical, equidistant standards, varying from four to six feet in height for truck to a height greater than the trees in orchards, constitute a second type of spray irrigation system. The nozzles are set from 30 to 50 feet apart. The advantages of this system are rapidity of application where this is desirable, comparative freedom from clogging, and satisfactory operation at low pressures. The disadvantages are uneven distribution of water due to uneven spread of nozzles and the overlapping of circular sprayed areas, and lack of adaptability to more delicate crops. The cost of installation is more than that of the movable hose system.

The stationary overhead system, the third type of spray irrigation, consists of raised parallel lines of pipe in which nozzles are set every few feet. The pipe lines may be rotated so that the spray will be directed at any desired angle between the vertical and 45 degrees on either side of the line. In this way areas about 50 feet wide can be watered by each line. The advantages of this type of spray system are adaptability to varying needs and evenness of distribution. The cost is about the same as that of the fixed nozzle system.

Machine Rifles. S. TRACK. (*Arms and the Man*, vol. lxi, No. 23, p. 443, March 1, 1917.)—Should the United States, ten years hence, be called upon to provide an army for active field service, there is little doubt that the weapons of the riflemen therein will be as different from the 0.30-calibre service arm as is the Springfield from the 60-inch Kentucky rifle of frontier days. While the present service rifle marks the high-water mark of development, ballistically, ordnance experts are bending every energy toward the selection of machine guns with which to equip the nation's fighting forces, and batteries of light and heavy rapid firers will play as important a part in future battles as light and heavy artillery have in the past. It is a generally-accepted belief that light and heavy types of rapid firers, capable of 300 to 700 shots per minute, will constitute the chief reliance of infantry campaigns in the future. If that prove true, it is considered likely that the heavy guns will probably be Vicars-Maxim, water-cooled, and Colts, each weighing in the neighborhood of 50 pounds with tripod. The lighter type will probably be Lewis guns, weighing 25 pounds, and Benet-Mercier guns, which weigh considerably more than the Lewis, together with a possible third type, the so-called portable Hotchkiss, weighing only 16 pounds, which will shortly be submitted to the United States for trial.

It is by no means certain, however, that the true machine gun will entirely remove the necessity of developing a smaller weapon of offence and defence, less effective in mass fire, perhaps, than the machine gun, which will be, in all probability, an adaptation of machine-gun principles to the army rifle—in short, a machine rifle.

An attempt is already being made to supply such a weapon. Not very long ago one was submitted to the War Department. This rifle,

while capable of functioning in every way claimed for it by its sponsors, was not accepted, chiefly because it weighs 10½ pounds. The ordnance experts believe that to be practical a machine rifle should weigh no more than 9½ pounds. The gun, a Hotchkiss, was manufactured at the Coventry, England, plant of that concern, and was designed to be purely and simply a shoulder gun, and is equipped with a bayonet. It is claimed that this machine rifle can be loaded with a 10-cartridge clip for rapid fire in less time than is consumed in loading the Springfield with its five-cartridge clip, and that a maximum rapidity of 100 shots per minute can be attained.

Inflammability of Carbonaceous Dusts. H. H. BROWN. (*Journal of Industrial and Engineering Chemistry*, vol. 9, No. 3, p. 269, March, 1917.)—The fact that coal-dust is explosive is very generally known to-day, though only within the last thirty years has it been fully recognized that coal dust alone is explosive without the presence of gas. Experiments have shown that many other carbonaceous dusts are at least as easily ignited and capable of propagating an explosion as coal-dust. While most of the dust explosions reported in surface plants occur in mills and elevators handling wheat, oats, and corn and their products, it appears that no mill handling carbonaceous material is immune from the possibility of explosion. The list of known explosions in other kinds of mills includes those handling dextrine, sugar, starch, malt, wood, linseed meal, cotton-seed meal, paper, cork, fertilizer, sulphur, cocoa, and spice dusts.

That flour dust will explode was clearly demonstrated in 1878 by a tremendous explosion in the Washburn Flour Mills in Minneapolis. This disaster aroused milling men to the danger of existing conditions and caused many to take immediate precautions against a repetition of a similar occurrence. The impression was not lasting, and, although a large number of grain-dust explosions occurred later, general interest was not awakened until June 24, 1913, when an explosion occurred in a feed-grinding plant at Buffalo in which 33 men lost their lives and over 70 men were injured. This explosion, which occurred during the ordinary process of milling, completely destroyed the mill and considerably damaged the surrounding property. As a result, an agitation was started between the millers and the Bureau of Mines for the investigation of questions relating to explosions of grain dust. This was later taken up by the Government and is being continued in coöperation between the Bureau of Chemistry and the Bureau of Mines.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA